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Directorate of R&D
FUTURE WEAPONS OFFICE

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SPACE INFORMATION BRIEFING

HELD AT

U. S. ARMY WEAPONS COMMAND
30 MARCH 1966

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(6) SPACE INFORMATION BRIEFING

HELD AT

U. S. ARMY WEAPONS COMMAND,
30 MARCH 1966.

(11) 1966

(12) 90p.

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U.S. ARMY WEAPONS COMMAND

Directorate of R&D
FUTURE WEAPONS OFFICE
ROCK ISLAND, ILL.

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INTRODUCTORY REMARKS

presented by

LT. COLONEL JAMES HILL

DIRECTOR, R&D DIRECTORATE
U. S. ARMY WEAPONS COMMAND

ROCK ISLAND, ILLINOIS

INTRODUCTORY REMARKS

(U) I would first like to welcome all of you to the Army Weapons Command. You who are here from private industry have previously shown an interest in participating in this Command's space program. It is sincerely hoped that the briefings today will stimulate thought, interest and coordination in such a program. You who are here from the Combat Developments Command and the Army Materiel Command were invited to become familiar with the work that has been done and the need for a much larger input than the Army is currently supporting. We must first make significant progress in identifying the problems associated with the hostile environment of space before we can hope to find solutions to problems once they are identified.

(C) Our national policy is clear: "Space should be preserved for peaceful purposes." However, we cannot assume that offensive space weapons will never be developed. Nor can we afford to wait until such a threat becomes a reality to develop an effective defense. Military space capabilities are developing rapidly. Much of the Soviet space activities are still clouded in the secrecy used to protect their military operations. The Soviet space program has been characterized by surprises, a condition often militarily fatal to the nation surprised. Such important Army guidance documents as the Combat Development Objectives Guide; the Long Range Technological Forecast; the Army 75 Concept Study; and the Intelligence Forecasts recognize the

rapidly advancing military space capability potential. They provide encouragement and general guidance in the form of QMDO's for future materiel research and development. If the Army is to continue to lead and avert surprise, an immediate exploratory program is required to:

a. Indoctrinate the technical individual in policy, mission and doctrine for space operations;

b. Define the threat in terms of the target, tactics, and size of operation;

c. Explore the damage mechanics associated with space targets;

d. Determine the capabilities and limitations of current weapons; and

e. Generate new concepts for military space operations.

(U) The series of briefings that you are about to hear is one step toward the indoctrination of personnel and the identifying of initial problem areas.

(U) Once again let me welcome you to the Weapons Command. I hope your visit here is both pleasant and fruitful.

LUNAR OPERATIONS

presented by

LT. COLONEL GORDON RIEGER

INSTITUTE OF ADVANCED STUDIES
COMBAT DEVELOPMENT COMMAND

CARLISLE BARRACKS, PA.

LUNAR OPERATIONS

(U) The United States has committed itself to placing a man on the moon and returning him to earth. While this event has been scheduled for 1970, various NASA sources have predicted that it could come as early as 1968. This is but the first phase of what promises to be extended exploration of the moon and the entire solar system. As an extension of the first landing, NASA is planning three 14-day lunar landing missions, these operations to take place in 1970-71, and a mobile lunar laboratory in which man could live for 45 days. This laboratory could be projected to the lunar surface in 1975. These events are all subject to budgetary considerations and the world political requirements. Beyond these plans lie only predictions and possibilities of things to come. Attempts will surely follow to establish permanent bases on the more accessible and least inhospitable planetary and satellite bodies. In fact, a group of distinguished scientists recently predicted that a temporary lunar base will be established by 1975 and a permanent base by 1982. It is to these bases that we direct our attention this morning.

(U) The reasons for this rush to the moon can be divided into three categories: political, scientific, and military.

(U) The political and psychological advantages of our being first to place a man and then establish an outpost on the moon are tremendous.

We have been challenged in science and technology by our chief competitor nation. Our primacy in these areas has been a source of national pride and a demonstration of our world leadership, and we dare not let this challenge go unanswered.

(U) Scientifically, a lunar outpost will support detailed exploration and investigation of the moon and serve as a launch site for future deep space exploration.

(C) Militarily, a moon base will extend and improve space reconnaissance and surveillance capabilities. It will extend and improve communications by serving as a relay station. Finally, it may provide an advantage for earth military operations or serve to deny this advantage to our possible opponents. The extent of this military potential is not yet clear. However, we cannot look at tomorrow's problems in terms of today's concepts and weapons and automatically conclude there will be no military use of the moon. We cannot wait for a demonstrated military use or stated requirement before initiating development of plans and materiel. We know Americans are going to the moon and we must be prepared to support them.

(C) Recognizing this fact and the possibility of lunar operations, the Chief of Staff directed the Army Ordnance Corps in 1959 to initiate a study for the establishment of a lunar outpost. This study concluded that it was technologically feasible and desirable to establish such a base. Last year, at the direction of the Combat Developments Command, we at the Institute of Advanced Studies took a look at projected space

operations in the 1975-85 decade to determine the military implications of space for the Army. We concluded that space has added a new dimension to combat on the earth's surface and that space travel and exploration will result in the assignment of new missions to the Army.

(C) While we believe that the Army in this time period will not be directly involved in lunar military operations, we do foresee requirements placed on the Army to take advantage of its unique and established talents, experience, and capabilities, particularly in the development, distribution, maintenance and repair of all classes of supply; the construction and maintenance of facilities; and the provision of decontamination services. You will hear from Mr. Harry Lowe about the construction effort, which is currently an active and tangible requirement, and I will confine the remainder of my remarks to weapons requirements and employment in the lunar environment.

(C) If the moon is determined to be of significant strategic importance, there is no doubt that it will be sought after by the great powers, and this competition could lead to conflict. While our stated national purpose is the peaceful exploration and use of space for all mankind, we may not be able to exercise that option on the moon unless we are the first to arrive because of the absence of a comprehensive body of law governing space and an enforcement agency. For these reasons, we must be prepared to resist, with force if necessary, any attempt by another nation to deny us the opportunity for peaceful access and exploration and to defend any lunar outpost or colony that

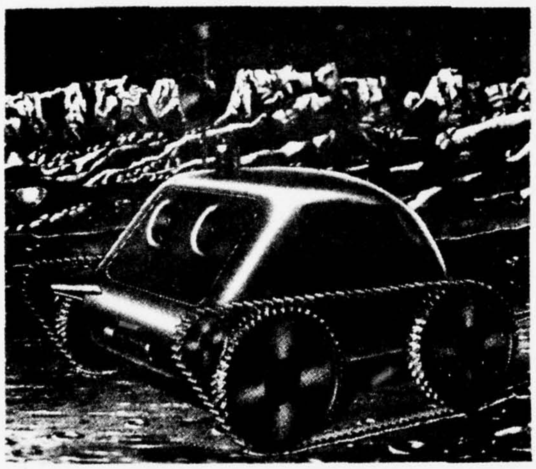
we establish.

(C) I am not saying that a strictly military force is required on the moon during this period. Undoubtedly, most of the first to arrive will be military scientists and engineers, multifunction trained, since the logistics problems dictate that each man must be trained to do the work of many for we cannot afford specialization in space. I am, however, pointing out that the lunar base and its people must be provided the means of defense.

(C) Whenever man has ventured into new and unknown areas his instinct for self-preservation has led him to protect himself from a hostile environment and to arm himself against the hostile competition of other men. In man's venture to establish himself on the moon both these needs will be present and both will influence the design of weapons intended to achieve a balance of force and thus promote peaceful coexistence in space.

(C) To better envision the performance requirements of lunar weapons, we must first postulate probable lunar operations after a semi-permanent outpost has been established. Initially, man will remain very close to the base shelter area, exploring his immediate surroundings to a distance of about one to two miles. Because of the small diameter of the moon, a man of average height disappears from view at about 1-1/2 miles. The unknowns of the moon make it desirable that the early explorer remain in visual contact with the base area.

After the outpost has been built up to a strength of about ten men, we visualize the use of a vehicle to extend this range to perhaps fifty miles. The constraints of payload will determine vehicular weight and configuration, and the vehicle may be a simple modified mule, unshielded and weighing about 1100 pounds or a more advanced, shielded vehicle. This vehicle would have a maximum weight of about 6000 pounds (of which 1/3 to 1/2 will be shielding weight), carry two people, and travel at about 5 mph. This shielding would probably consist of about 1" of aluminum and 4" of polyurethane foam. An artist's conception of one such advanced vehicle is shown in this illustration.



(C) Initial operations will be primarily base construction designed to transform the total environment to conditions most favorable and tolerant to human life and activities. Once the hostile environment is transformed, continuing long range exploration of the moon and establishment of an astronomical observatory and an interplanetary spaceport is envisioned. It is not likely that these latter operations will take place prior to 1985. However, when the development of the moon base does reach such a stage, it is believed that the Army will inherit many of the inherent tasks and that a small military force will be maintained on the moon to protect the colony and to further the

interplanetary objectives and policies of the United States.

(C) An enemy threat to a lunar base may come from any or all of three sources. These are personnel or surface vehicles from another lunar base, weapons from moon orbiting vehicles, and weapons from non-orbiting space vehicles. Each type of attack presents a somewhat different set of problems but the defense against all has the same objective: Prevent the destruction of the base shelter. The hostile environment of the moon is such that the loss or destruction of the base shelter foredooms the personnel dependent upon it.

(U) I am sure that you are all familiar with the physical characteristics of the lunar environment, but let me briefly list the more important ones which affect weapon design. Mr. Wagner will go into more detail on the specific individual effects.

Essentially no atmosphere
(hard vacuum)

Surface gravity/one-sixth
of earth

Surface temperature range
$+250^{\circ}F$ to $-250^{\circ}F$
120 C   -130 C

Rapidity of change -- roughly two hours

Relatively near horizon

(C) The logistics problem will dominate all other considerations. Every piece of equipment sent to the moon will have to be multi-functional. A weapon designed for space use should have a structural use during flight to minimize the logistics burden on lift-off.

Ideally, such a weapon would use ammunition indigenously available. We are likely to find large quantities of stone and meteorite particles on the surface of the moon and there will be an ample supply of radiant energy from the sun. Serious consideration should be given to the design of weapons which could be easily manufactured at the lunar base and use available materials for ammunition.

(C) In addition to these physical factors, there are certain human factors which also affect weapon design. On the moon we will be dealing with a completely enclosed man with significant loss of mobility, sensing, and dexterity. The latest model spacesuit approved by NASA is shown on this illustration.

Note the difficulties in sighting and firing. Only unsuited within a base shelter will man approximate his earthly capabilities. Therefore, remote sensing and firing will be premium qualities in any area weapon system.

(C) These characteristics and the nature of the threat suggest varying types of defensive weapons, ranging from the very simple (a means of propelling gravel) to the most complex (beamed electromagnetic

radiation) with all sorts of possibilities in between.

(C) Let us look at the requirements generated by the various threats in the light of the peculiarities of the lunar environment and tick off some of the pertinent points.

(C) Hostile Personnel or Surface Vehicles From Another Lunar Base. Here the problem is one of puncturing the pressurized vessel and letting the lunar environment do its work. Against a vehicle, this would take the form of puncturing the heat transfer unit, thus disabling the vehicle by aggravating the heat dissipation problem inherent in a vacuum. Undoubtedly, the spacesuits and vehicle skins will have some sort of a self-sealing ability so the requirement is for a fragmentation device capable of multiple gravel-sized punctures to overwhelm the self-sealing capability and to compensate for the inability for precise aiming and firing. The vacuum and low gravity of the lunar surface give us very good fragment ballistics, but the weapon must be capable of being focused because of the omnidirectional effect of fragmentation. A handheld claymore device is an example of a current weapon modified for the lunar environment. This sketch gives an illustration of the concept.

Note that the shape lends itself to structural use. The environmental effects on this weapon, however, are many. The vacuum works to our disadvantage in explosive initiation and propagation. Redesign of present detonators and percussion primers is required to insure reliable operation in a vacuum. The extreme variations in temperature and the rapidity of change virtually rule out the use of TNT as an explosive, since it becomes molten at about 175°F. The lack of animal and plant life on the moon seems to rule out finding the basic chemicals required for indigenous manufacture of explosives and propellants. Therefore, we should strive to find new sources of energy for use in space.

(C) Hostile Space Vehicles. Essentially the detection, tracking, and destruction of these vehicles is no different from that on earth with the exception of choice of weapons. I might mention here that detection and tracking of non-orbiting vehicles would in fact take place on earth and the required firing data communicated to the lunar base. Because of the vacuous conditions around the moon the radiation effects of nuclear warheads are greatly enhanced; thus the space vehicle itself, its electronic components, and warhead are particularly susceptible to radiation destruction. This suggests emplaced nuclear-armed missiles or beamed electromagnetic radiation weapons. The constraints of weight would seem to rule out transporting a missile system to the moon, while the abundant solar energy seems to place a premium on the development of energy beam weapons.

(C) Taking all the situations together, the specific defensive

weapon requirements for a lunar base appear to be:

(1) A small arms for use against personnel, capable of firing a buckshot or scatter type ammunition. The triggering mechanism of this weapon must be compatible with the spacesuit. We would look for this to accompany the earliest travelers.

(2) A larger version of the same type weapon for use against groups of personnel and surface vehicles. This weapon would fire a large volume of high velocity fragments in the general direction in which aimed. Again triggering must be compatible with the spacesuit. A possibility here is the electrostatic projection of pellets as an alternative to chemical propellants.

(3) An emplaced directional mine for perimeter defense. Again we are talking about firing directionalized high velocity fragments. This mine must be capable of direct or remote control firing. Complementing this should be omnidirectional fougasse randomly placed around the defensive perimeter.

(4) A weapon preferably of directed beam design to be used against space vehicles. The special circumstances of the moon environment favor the use of radiant energy.

(U) These are examples logically extending from today's technological capabilities and the requirements for defensive weapons. They are presented only to put you in the proper frame of mind and to stimulate creative thinking. My main purpose has been to set the operational environment in space in future years. I am sure that you gentlemen,

with your interest in the field of weapon design and production, will be able to come up with weapons concepts entirely new and in keeping with our visualization of the lunar environment and lunar operations.

THE MOON AND LUNAR CONSTRUCTION

Presented by

MR. HARRY N. LOWE, JR., CHIEF

EXTRATERRESTRIAL RESEARCH AGENCY
OFFICE OF THE CHIEF OF ENGINEERS

WASHINGTON, D. C.

THE MOON AND LUNAR CONSTRUCTION

(U) Several months ago I received a letter which read as follows:

"Dear Sir:

"Please send me all you know about the universe.

"Yours truly,

"P.S. Please make the information short because my teacher says I cannot write more than 500 words."

At first I was amused by this letter from a little boy who wanted to describe the universe in not more than 500 words. Only after reading it a second time did I comprehend the real challenge of his request. He had asked, "Please send me all you know about the universe." This kid wanted the facts. Frankly, I found the limit of 500 words entirely satisfactory.

(U) Today I am concerned with a very, very small part of the universe. My subject is The Moon and Lunar Construction. My task is to compress 5 billion years of the past and 25 years of the future into 30 minutes of the present.

(U) If I limit my remarks to what I know about this subject, I will spend most of this period telling old jokes. Fortunately the purpose of this meeting is to encourage us to think about the moon and related problems that may develop in the years ahead. It is proper and fitting, therefore, that I speak of both, what I know and what I

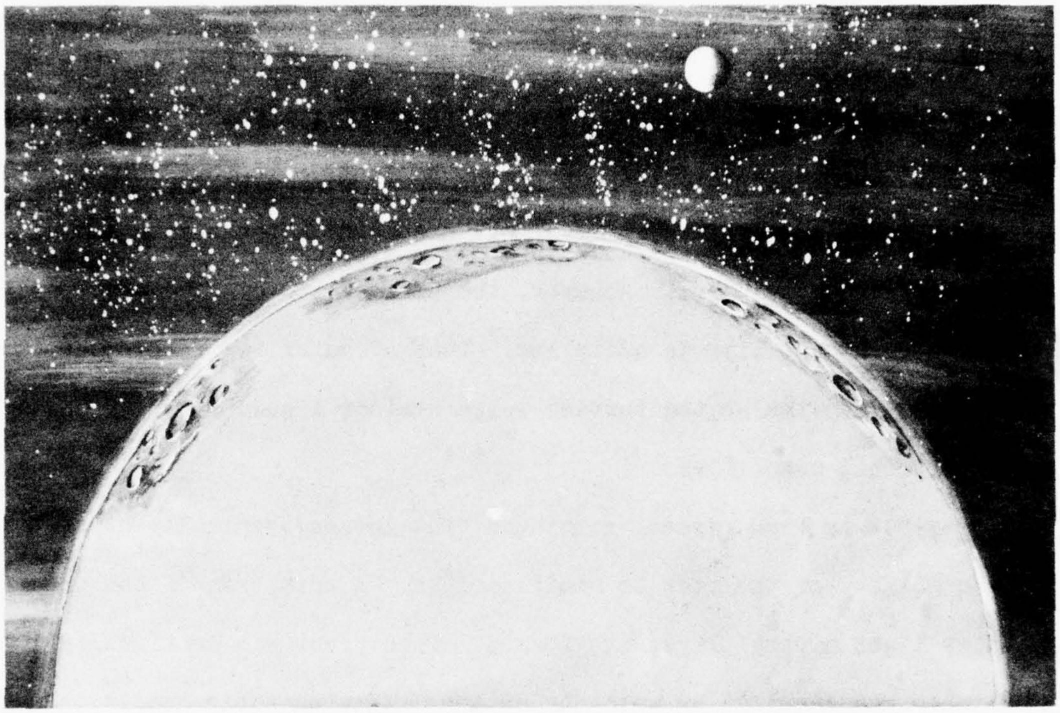
believe. In this way I will certainly use all of the available time and I may contribute to the objective of this meeting.

THE MOON

(U) Origin. Five billion years ago, give or take a fortnight, the space now occupied by the solar system was filled by a young sun surrounded by a cloud of dust, sand, gravel and boulders. At one particular spot the density of this cloud of particles became so great that a local gravitational field was produced. In time this local zone of influence produced a small aggregation of material capable of attracting to it other particles in near proximity. At that point in time the embryonic moon existed. Thus, through aggregation of cold particles, the moon was born and grew - and grew, and grew. Elsewhere within that cloud, other bodies were forming in like manner. These other bodies we now know as the planets and the other features of the solar system; but that is another story. Now back to the moon.

(U) Evolution. The initial formation and growth of the moon was followed by a series of reactions. The first was evolution of heat. Thermal energy evolved from two sources. One was physical interaction between the solid particles such as impact, shear, friction and compaction. The second was radioactive mineral decay. Heat evolved in the outer zone was quickly dissipated. However, heat energy within the mass had difficulty escaping through the outer surface of loose aggregate. Thus, the temperature of the interior of the mass rose

higher and higher until there was either melting or a high state of plasticity. Concurrently, the heated mass expanded but did not break through to the surface. Thus, continued heat evolution, now principally by radioactive decay, melted the entire planetary mass.



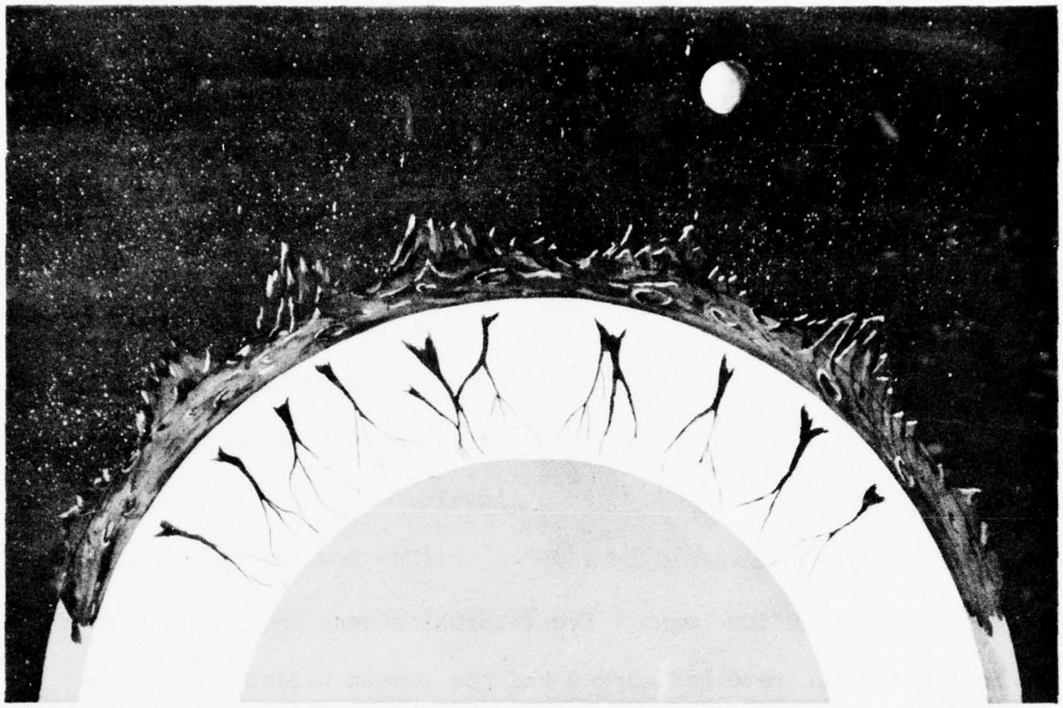
(U) Concurrently, two important reactions took place. The first was mineral formation and magmatic differentiation. The second was simply the loss of heat to space at relatively high rates. The first produced new and complex minerals and permitted them to segregate in accordance with their weights. The second reaction made possible the formation of a new crust as the surface cooled.

(U) Now about this time the earth was guilty of its initial sin. It kidnapped the moon. The evidence of the crime is the so-called tidal bulge on the moon's surface, which testifies to the existence of a relatively limber or plastic crust at the time of capture.

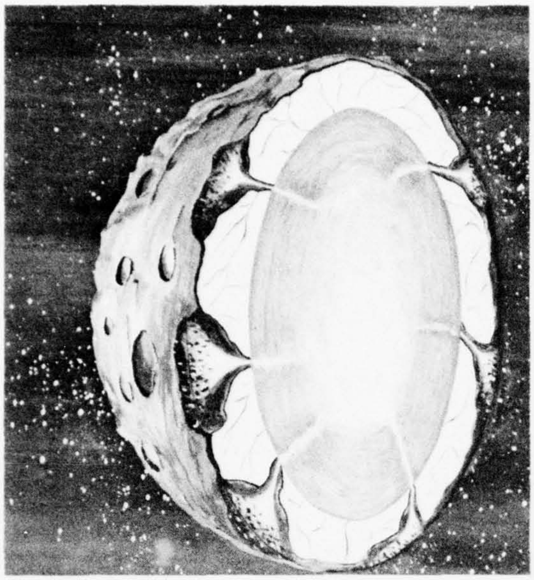
(U) Following capture by earth of the still hot protomoon, degassing of the luna magma continued. For a reasonably long period of time this degassing was sufficient to equal or exceed normal atmospheric loss. Thus it is highly probable that the moon had an appreciable atmosphere. However, the possibility of free water on the moon at any time is quite low. Loss of water vapor to space coupled with the heated surface rules against liquid water in any significant quantities.

(U) As time passed, continued heat losses eventually exhausted the ability of the mass to remain molten. A thin skin of the outermost light mineral layer was formed. This crust was continually broken and engulfed by volcanic action. This unstable condition until further loss of heat permitted a thicker and more stable crust to form.

(U) As this crust formed, it was subjected to a rain of meteoroids that produced impact craters of all sizes. In the case of very large meteoroids, the large basins resulting produced zones of weakness in the crust that were to play important roles in further development of the moon.



(U) The moon had come to a critical point in its evolution. A thick crust had formed. Below the relatively cool crust, the semi-molten interior had ceased to lose any significant amount of heat. The center was heating to higher and higher levels and internal pressure was building ever higher. Finally the tensile strength of the crust was exceeded. Long fissures appeared at the weak zones in the deep craters. The heated material below flowed up these fissures in large volume, cooling but little as it rose. In a state of high fluidity the molten rock poured forth, flowing far and fast. Like any fluid, it sought the low areas. However, in response to its energy of flow, it



flowed up relatively gentle slopes, overwhelming some pinnacles and flowing into lesser craters. Evidence of this flow activity is present on the lunar surface today. Successive eruptions eventually filled the large basins to their present levels.

(U) Now the current phase of the moon's evolution began. The internal stress had been relieved, its heat evolution rate had slowed and the planet became relatively quiescent. Whether this is a temporary phase or for all time depends upon the current potential for heat evolution. Future manned exploration of the moon will not only shed new light on the history of the moon but may also provide information on its future as well.

(U) The Moon Today. The moon as we know it today is the result of 5 billion years of actions and reactions. That result is a satellite of earth, measuring 2162 miles in diameter and orbiting the earth once in approximately 28 days. The average distance from earth to moon is about 239,000 miles. Because it rotates on its axis in about the same time as it orbits the earth, it always presents the same face as the earthbound observer. Man knows a number of things about the moon and its environment. He has supplemented his knowledge with

considerable speculation. A summary of some of this knowledge and speculation is contained in the U. S. Army film titled, Man On The Moon. This movie was prepared before the successful flights of Project Ranger and Luna IX. However, I see no reason to revise the film as a result of these later observations.

Lunar Construction

(U) This nation does not now have a lunar construction capability. The primary reasons include:

a. Lack of lunar data.

b. Lack of knowledge concerning the performance of men and machine systems in the lunar environment.

c. Lack of decisions by this nation that would define the time and scope of need for a lunar construction capability.

The first two of these deficiencies do not disturb me. Lack of knowledge is dangerous only when the deficiency is not recognized. The third deficiency is lack of decisions. This one disturbs me. To better understand the importance of these decisions on future lunar programs, let us review some recent history.

(U) The Army Engineers have been actively engaged in lunar construction research since 1957. Of our early activities, the most noteworthy was Project Horizon. This project was an in-house lunar base concept and planning study conducted in 1959 by the Technical Services of the U. S. Army under the coordinating direction of the

Commanding General, Army Ordnance Missile Command. The study report concluded that a manned landing on the moon by 1965 was technically possible and that a 12-man lunar base could be operational in 1967.

(U) The design concept for the Horizon base was an outgrowth of earlier studies by the author in which a concept was developed for an 8-man temporary lunar base.

(U) In 1959 this nation was not prepared to make a decision for action relative to a lunar base.

(U) From 1959 to 1962 the Army Engineers continued to study the problems of constructing on the moon. In May 1960, interim results of these studies were covered in testimony by the Chief of Engineers before the House Committee on Science and Astronautics. These studies produced the following conclusions in 1962:

a. In the absence of a "crash" requirement, 10 or more years must be devoted to an applied research and development program to develop a lunar construction capability.

b. The scope of potential problem areas is so great that an undirected research and development program is essentially impractical. To channel efforts and funds, requirements for construction capabilities must be defined in detail and the research and development effort restricted to achievement of these defined capabilities.

c. To design and construct lunar bases, the engineer must be provided with additional data concerning the physical structure and the environment of the moon. High priority should be assigned to

acquisition of astrophysical data required in planning, designing and constructing a lunar base.

d. Of the factors influencing design of lunar bases, the characteristics of the space vehicle system will be among the most important. The design of bases will be influenced directly by the dimensions, payload ratings, and flight stability characteristics of the delivery vehicles. Potential problems in this area are of such import that, initially, lunar base construction concepts should be developed concurrently with the conceptual design of lunar cargo vehicle systems.

e. Conventional laboratory and testing facilities will not meet the full range of requirements of a lunar construction development program. Basic and uncompromising requirements exist for manned facilities on earth in which the lunar environment is stimulated, including lunar soil. Such facilities are required for identification and solution of construction problems, development of design criteria, design verification testing, systems integration and evaluation, acceptance testing of hardware, and for training personnel. Required facilities are within the state-of-the-art.

f. A minimum level effort toward development of a lunar construction capability will require an in-house research and development team of approximately 460 workers supported by the industrial and scientific community under contract, new facilities totaling approximately $25 million in capital investment, and a

technical program costing in excess of $200 million in this decade.

(U) In 1963 these findings were published by the Army Engineers as part of a study for NASA of the problems of developing a lunar construction capability.

(U) In 1963 this nation was not prepared to make a decision relative to developing a lunar construction capability.

(U) During the past two years there has been much discussion of what should be the U. S. space objectives after successful completion of Project Apollo. Among the possibilities discussed is intensive exploration of the moon from bases on its surface. This discussion has not yet led to action. There is, however, a growing body of informed opinion that holds that action must come soon, perhaps next year.

(U) In 1965 and 1966 this nation was not prepared to make the decisions that would define the time and scope of need for a lunar construction capability.

(C) In light of this recent history, will these decisions be made in the near future? In the absence of unforeseen developments, I think the answer is yes. On this assumption, it is then possible to postulate the possible course of U. S. manned lunar activities over the next 20-25 years to include the relationship between military and scientific programs.

(C) 1965-1970. This period will emphasize preparation and planning for the manned Apollo landings. Military activities will be limited to cooperative support of NASA and identification of data needed to support military planning. The relationship of military and scientific activities will be described by the word "Cooperation."

(C) 1970-1975. This period will emphasize exploitation of Apollo systems to increase stay time on the moon to 28-45 days and to accomplish lunar exploration. Military programs will include a start on developing a lunar construction capability and design of experiments to be carried out on the moon as part of the National Manned Lunar Program. The relationship of military and scientific activities will be described by the term "Integrated Efforts."

(C) 1975-1980. This period will emphasize lunar exploration and extension of capabilities to stay on the moon for periods up to three months. During this period a small temporary manned lunar base will be operated as a joint DoD-NASA project. The mission of this base will be to support research and experimentation. The relationship of military and scientific activities will be described by the term "Joint Programs."

(C) 1980-1990. This period will witness a maturing effort of lunar and deep space exploration and exploitation of the military and scientific values of lunar bases. During this period a semipermanent manned base will be constructed on the moon. Its mission will include support of military and scientific research as well as accomplishment

of assigned military tasks. In this period data will become available on which to make decisions concerning the long range role of the moon, if any, in both scientific and military space activities. The relationship of military and scientific activities will be described by the term "Mutually Supporting."

I am well aware of the danger of speaking about an American space effort without giving concurrent attention to the possible course of future activities of the U.S.S.R. I hope that we are sufficiently mature in our space programming to understand that we need a program of action, not just a program of reaction to Russian activities. I don't know what the Russians are going to do. I am not even sure the Russians know. In my ignorance I satisfy my needs for knowledge of Russia's future activities by remembering the words of Professor Tsiolkovsky, the father of Russian space thought. These words are chiseled into the stone that marks his resting place:

> "Man will not stay on earth forever; but in the pursuit of light and space will first emerge timidly from the bounds of the atmosphere, and then advance until he has conquered the whole of circumsolar space."

I doubt that he was thinking exclusively about the exploits of future American astronauts.

MATERIALS IN A SPACE ENVIRONMENT

presented by

MR. BERNARD RUBIN

ANALYSIS & REQUIREMENTS BRANCH
APPLICATIONS DIVISION

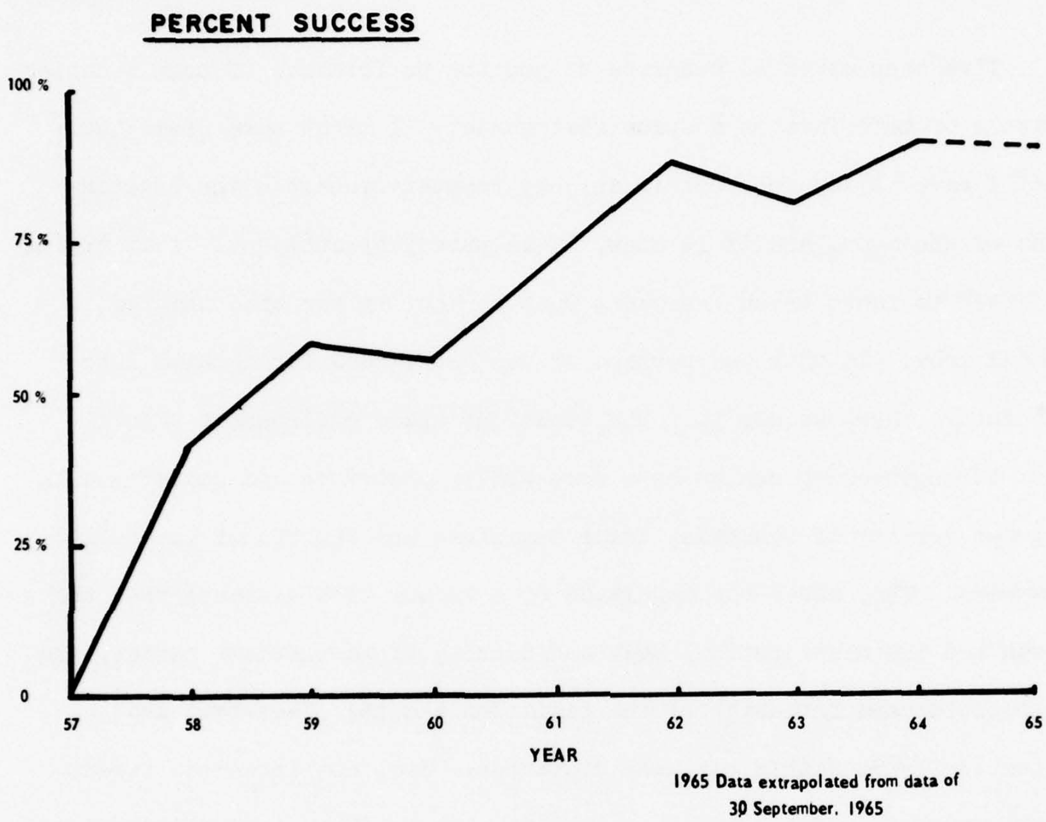
U. S. A. F. MATERIALS LABORATORY

WRIGHT PATTERSON AIR FORCE BASE, OHIO

MATERIALS IN A SPACE ENVIRONMENT

I've been asked to describe to you the performance of some selected classes of materials in a space environment. I might make clear that what I have to say does not in any way remotely resemble the environment of the moon, and if it does, it is purely by accident. I am trying to stick to facts which represent what we know rather than what we should know. In this way perhaps we can get a feel for looking into the future where we may go. The facets of space environment significant to engineering design have been widely described and summarized in a great variety of journals, trade magazines and reports of government agencies. They cover the magnitude of a vacuum with distance from the earth and the distribution, mass and density of particulate matter, the composition and intensity of the radiation and the electrical and magnetic fields within cislunar distances. I do not intend to repeat these statistics here; only to point to them as the reason for your concern with a different environment. Some of the **unforeseen failures** of space probes resulted from unexpected changes in engineering materials brought on by exposure to the space environment. That scientists and engineers have learned to define in advance and cope with such changes is shown by the steady increase in spacecraft reliability since the first launch in 1957. There are now several launches a month by the Department of Defense and here is a record. As you can see, as we

advance in years the percentage of successes is showing a significant improvement.



Most of these items when they enter space perform with some reasonable degree of success. What kind of effects can we expect which are partly due to the natural environment of space? Effects in both the bulk characteristics and the surface characteristics have been recorded. The bulk effects are largely due to radiations of sufficient intensity and duration to cause ionization and dislocation reactions, and to gross damage due to particulate matter. The surface effects are

often thermal optical in nature. Properties such as emittance, absorptance, reflectivity, and mechanical such as sliding friction, cold welding and adhesion. All components of the space environment can contribute to changes in the original properties of the exposed surface. Much of our knowledge about the effects on materials has been acquired in simulation facilities and practically any single phase of the space environment can be simulated, even and including zero gravity. As a side remark, I might point out that I have personally experienced this myself in a zero gravity laboratory, in a KC 130 flight and have been sick during the whole hour while I was engaged in such a flight three years ago. However, eventual confirmation of ground evaluation data must be and is being obtained in the actual environment in order to provide validity and realism to engineering design. Two points should be made before we review specific effects on particular kinds of materials. First, the space environment although different is not necessarily detrimental to materials performance. In fact, it may be benign, when one considers freedom from oxidation and atmosphere induced corrosion. Second, for any device used in space, the problem of material selection resolves to a choice of materials that will perform in both the earth and space environments. It is an impossible task to summarize in a realistic fashion the effects of a space environment on the mirads of materials with diverse functions which are used in space vehicle design in the short period while we are here. Consequently, I

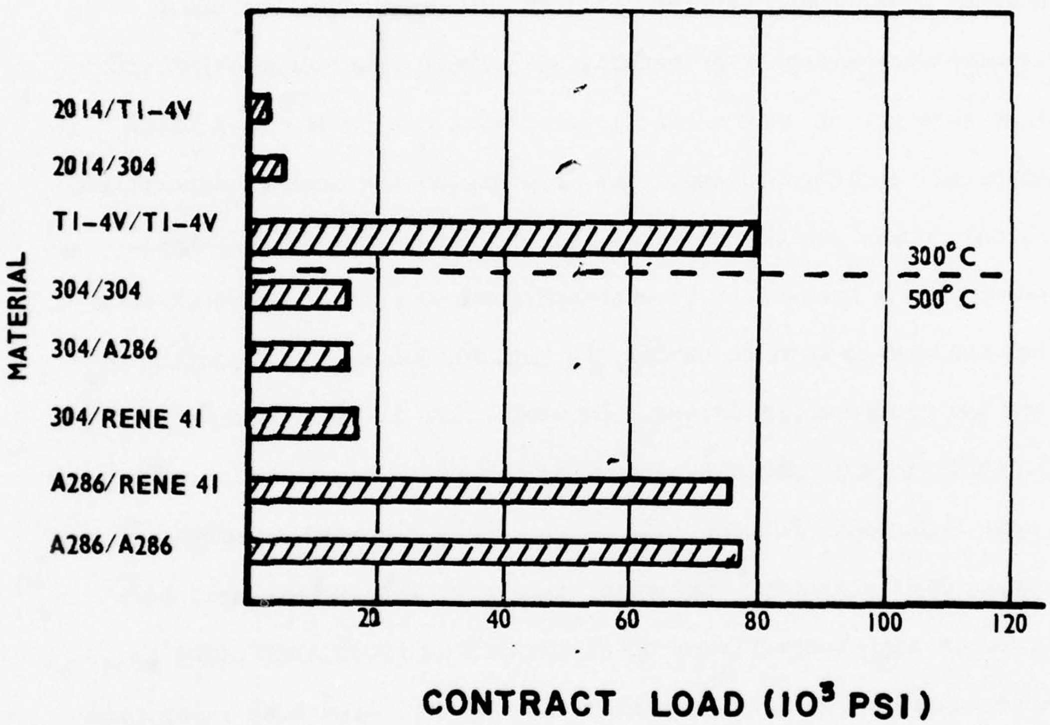
will attempt to direct my remarks to some highlights on a few material areas. In considering the structural materials we find that metallic structural materials are used for load carrying components such as fuel tanks, outer shells, and membrane structures. All the high strength alloys based on magnesium, aluminum, titanium, beryllium and stainless steels are potential candidates for materials. Equally, the high strength filament reinforced plastics have found use in vehicle skins and stiffners in supporting structures both when used as stiffened panels and in sandwich construction.

I do not have a picture of a typical unmanned spacecraft but if you look at it, it is sort of a box in which you stack things. The electromagnetic transparency of the high strength reinforcing plastics have also been explored for radomes and antennas as well as for high-frequency communications, telemetry, and detection devices.

What about some of these specific materials? The specific environment per se had suggested some potentially unique problems in the use of metals. There was anticipation of localized loss of metal changes in mechanical properties associated with the loss of adsorbed gas layers, and variations in temperature due to orbiting modes. None of these problems have, in fact, as yet proved to be of a significant magnitude to be seriously detrimental to structures because of the ingenuity of the designers. For instance, of all the metals I have just mentioned, magnesium is potentially the most volatile. Such loss of metal from a film-free surface can be computed theoretically from

the Langmuir equation. In case of magnesium, the computation shows losses in the order of .004 of an inch in the course of one year at temperatures of about 400°F. However, the Langmuir equation predicts only maximum rates. Actual observed rates are always lower even in simulation facilities. Further, loss rates can be substantially reduced by a very thin barrier coating. In one sense, the space environment may actually be beneficial. There is evidence that the fatigue strength of some metals is increased due to the lack of an atmosphere. It is postulated that in a vacuum the loss of adsorption, which only coats the micro-cracks, allows the cracks to self-heal. On earth when a cracked surface becomes coated with adsorbed gaseous molecules it will tend to hinder the healing due to the formation of oxides and adsorbed gas layers. However, with the exception of fatigue life, no large strengthening effect of vacuum on mechanical properties has been reported. Fatigue life is generally reported as unchanged or increased just slightly. Radiation damage to metals have only been observed in high total fluxes on earth such as those that might be obtained close to nuclear reactors. At the very high dose rates, and here I am talking in the order of 1×10^{19} neutrons per square centimeter or higher, static embrittlement takes place resulting in increase in hardness and decrease in creep properties, plus some changes in other physical properties. Proton damage that one would worry about in space probably requires comparable dose levels.

Cold welding of clean gas-free polished surfaces can and does occur, but studies on adhesion and bare metal friction in a high vacuum environment has suggested the means by which cold welding can be either accelerated or prevented.



Here is some Hughes Aircraft Company data in which the interest is in determining the non-cold welding materials combination. They deal with metals such as aluminum, titanium, and stainless steels. The Rene 41 is a nickel alloy used to a large extent in many of our newer engines. The bar graph shows the limits at which neither adhesion nor cohesion occurs at a pressure of 10^{-9} torr during a 20 hour period. As you can

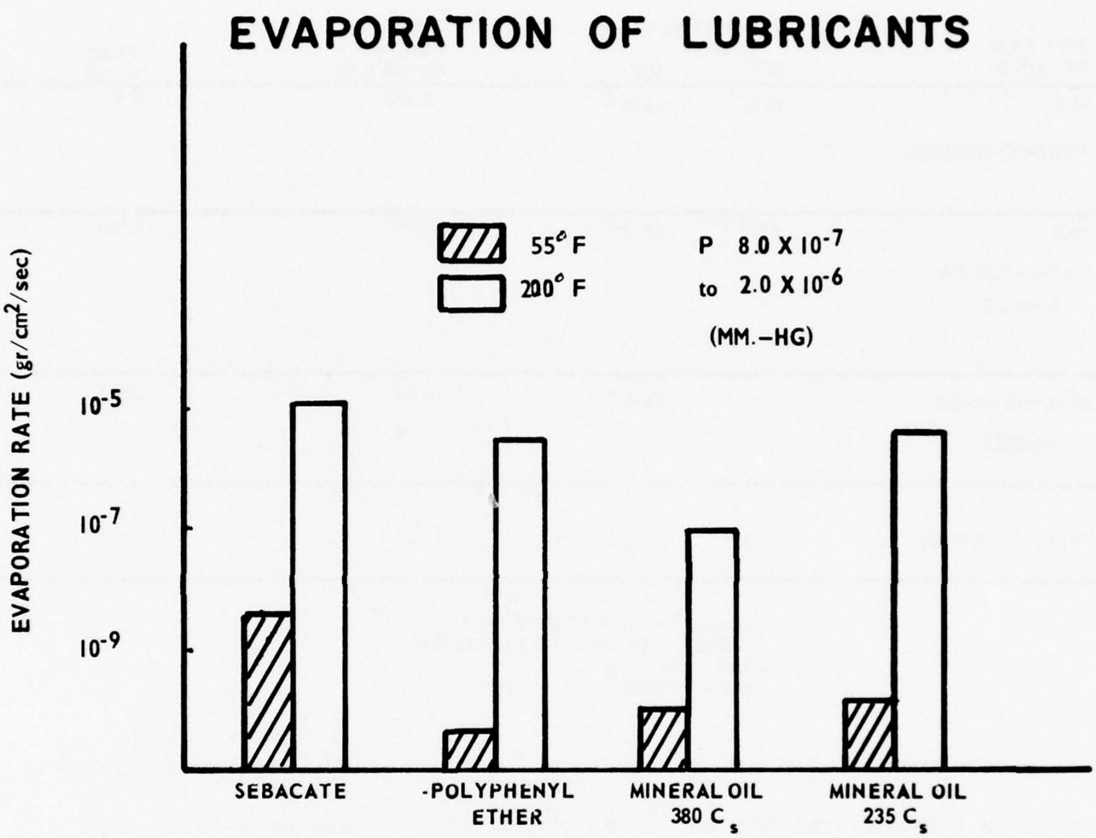
see the contact loads got rather high even though the temperatures were high, so that here one might assume that at lower loads the same data would be applicable. This gives you some conservative judgement for design. Cold welding in itself, of course, is not necessarily a detriment. We have talked of doing things in space and perhaps cold welding represents a method of joining. We should consider this. Most of the organic materials used in spacecraft are long chain polymer compounds which degrade in vacuum or the combined environment of space by breakdown of the long chain into smaller and more volatile fragments and not by direct evaporation or sublimation.

Fragmentation of polymer chains can be due to strong radiations which induce secondary ionizing reactions and by elevated temperatures which induce pyrolysis and subsequent scission of the long chain polymer. Consequently, the Langmuir equation, that I mentioned earlier, which incorporates vapor pressure data to establish evaporation losses at particular temperatures and pressures is useful in metals and for short chain compounds. It is not useful for the long chain polymer since it does not evaporate but sublimes. Generally, you have to do emperical weight loss studies if you want to get any information in either singular or combined environments for this particular facet of the operation. A wide variety of uses of organics has developed. For instance, as structural plastics, as adhesives for joining, as electrical insulation, as sealing applications, and a thermal insulation. Foamed polyurethane between like metal plates has been demonstrated to be an excellent

hypervelocity particle stopper in the lower ranges of masses and velocities common to the meteroid environment. The USAF Materials Laboratory, of which I am a member, has recently done some work which has demonstrated the feasibility of using the naturally occuring polymer gelatine for application as a pre-packaged expandable structure capable of being rigidized in space. This has been tested on earth, I might add.

How about moving surfaces? The function of a lubricant in a load bearing application has to prevent wear, reduce sliding and rolling friction, exclude dirt, and carry away heat. Lubricants and friction reducing materials are essentially, therefore, surface contaminents. Naturally occurring films formed on bearings due to the presence of atmosphere, as the oxides, absorb gases and moisture assist in this function. The new environments immediately bring concern that lubricants would not be effective due to the evaporation losses in a vacuum and the destruction of the atmosphere formed film which prevents the adhesion of some of the unlubricated surfaces when they come in direct contact. Metal films on moving surfaces are an efficient boundry lubricant in many cases. One response to a problem such as this is the use of a laminar solid film such as molymirdium disulfide bonded to the surface by some form of a matrix material. Plastics such as teflon and films in the above forms, and metallic coatings of silver and gold have also functioned successfully under intermittent use both in high vacuum and

in space. The typical patterns of evaporation loss and wear data on a moly disulfide contained dry film are shown on the following graph.



Sebalate is a common ester oil used in many of our instruments. Polyphenyl ether is a radiation resistant oil developed for nuclear use and here are two mineral oils of different viscosity. At the temperature and range as shown on the graph (in order of 10^{-7} to 2×10^{-6}) you have to get fairly high to get significant loss rates in terms of grams per square centimeter per second. Oils can be used in space under proper

usage. Laboratory friction, wear data, and moly disulfide contained dry films are shown on the following graph.

DRY FILM MATERIAL	EVAPORATION RATE g/cm/sec 50°F	350°F	COEFF. OF FRICTION ON 440 C/SS	WEAR IN^3/HR
MoS_2 CERAMIC-BONDED	$1X10^{-8}$	$1X10^{-8}$	0.306	0.4
MoS_2 METAL-MATRIX BONDED	$8X10^{-9}$	$8X10^{-9}$	0.10	0.015
SILICONE-RESIN BONDED		$2X10^{-9}$	0.03	0.001
PHENOLIC-EPOXY	$8X10^{-7}$	$8X10^{-9}$	0.022	0.0002

PRESSURE – $8X10^{-7}$ TO $2X10^{-6}$ mm Hg
SLIDING VELOCITY – 390 FT PER MIN
LOAD – 1000 gms
TIME – 1 HOUR

The resin bonded lubricant is superior for the normal temperature ranges. For high temperatures the use of an organic film would have to be considered, however. Screening studies such as these on a wide variety of lubricants and bearing lubricant combinations have pointed to lubrication materials and lubricating techniques which can be used in space environment. For instance, recent simulation tests on components have indicated that a special grease and a single charge can successfully lubricate double shielded high precision bearing (such as are found in

small electric motors) for a period of two years. This demonstration was conducted with a silicone oil grease at a speed of 8,000 rpm in the 10^{-6} to 10^{-9} torr region. A range of dry lubricants typical of current unmanned spacecraft can be seen in NASA's orbiting geophysical observatory vehicle which also uses hermetic seals for critical parts to get around the loss of lubrication. Exposed shaft and drive bearings are coated with gold, one set of gears uses sintered bronze impregnated with molydenum disulfide. There are some 250 louver bearings coated with a mixture of silver and moly disulfide. Good results have been obtained with silicone oils and greases in light load applications, The successful mechanism in the TIROS II weather satellite was based on the controlled loss of lubricant from a reservoir. This controlled loss of lubricant was precalculated on the basis of a molecular flow resistance equation, essentially a variety of the Knudsen diffusion equation, which worked quite successfully. As we note the TIROS has been giving us useful data. The natural radiation environment offers no problems to lubricants in space since almost all areas of lubrication are naturally shielded. The event of nuclear reactors for power uses with their much higher flux would, of course, change all of this. The single largest unresolved space lubrication problem, I believe, will involve mechanisms operating under heavy load conditions, particularly if these loads are combined with elevated temperatures.

When you put things together, you have to join them. In joining,

I would like to talk briefly about some adhesives. Adhesives for aerospace application are predominately organic, high polymer materials and are used in structural, non-structural, and optical applications. Structural adhesives are for applications in bonding of primary spacecraft structures to themselves and to each other. These bonds may be metal to metal or reinforced plastic panels either honeycombed or in sandwich construction. The adhesives are chemically typified by polymers such as the epoxys, polyurethane phenolics, and certain silicones. They generally require elevated temperatures for curing under pressure. Structural adhesives are generally elastromeric or thermal plastic and typical examples are air dry solvent systems of natural synthetic rubbers such as silicones, neoprenes, and nitriles. They may be used for items such as gluing all covers under solar systems - glass covers. Special ceramic adhesives for use at temperatures about 1000°F have also been developed. Important properties which must be considered by the designer and which are prone to degradation by an environment are tensil and shear strength, yield strength, creep, optical transmission, and thermal limits. Adhesive selection also depends upon design factors which are not a function of the operating environment or related to the form of the adhesive and its processing characteristics. The principle environments affecting the quality of the adhesive bonded structural joints in spacecraft are high and low temperaturs, nuclear radiation, and high vacuum. For optical application such as the

bonding of solar cell covers and optics external to the spacecraft ultra-violet radiation, nuclear radiation, and temperature extremes becomes of immediate concern. What can be said regarding the polymeric adhesives under the influence of the natural space environment at least as far as our simulation shows and some of our data acquired from the operation of near space vehicle shows? Within a range of temperature of between 100° to 400° the adhesives will perform satisfactorily and follow the limits observed in laboratory and ground simulation studies. Most structural pieces perform well under radiation conditions found in space. In fact, if one extrapolates, one can estimate perhaps a five year life. The amount and nature of shielding material over the adhesives obviously extends its performance reliability, and useful life. Bonded joints present very little adhesive surface to the vacuum environment and, of course, inherent materials are relatively impermeable to gases. The effects of vacuum on mechanical properties are insignificant for most applications.

The affects of combined environments of vacuum and elevated temperatures are shown in this graph.

LEAKAGE RATE (10^{-6} (STP) CM^3/SEC)

ΔP 1 ATM.

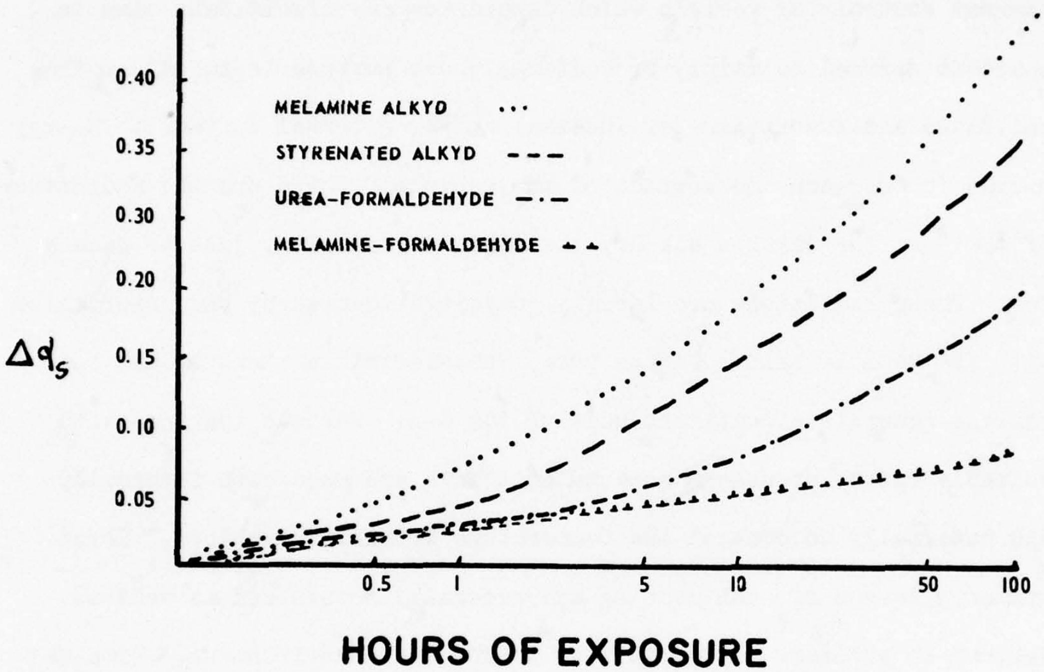
CONTROLS		864 HRS AT 200° F 312 HRS AT 250° F ALL AT 10^{-6} TORR	IRRADIATED 3.4 X 10^{-7} RAD AFTER AGING
1. EXPOXY			
(a) LIQUIDS	1	1	2.3 TO 20
(b) UNSUPPORTED FILMS	1	1	
2. SILICONE	1	1	0.15
3. SPOXY PHENOLIC			
(a) LIQUID	1	1	20
(b) SUPPORTED FILMS	1	20	TOO LARGE TO MEASURE

These numbers refer to the leakage rate in terms of 10^{-6} cubic centimeters per second under the condition shown here. The controls show that the loss should be less than one for all of these different adhesives in different forms. I mentioned liquids, supported films and support films. However, you will notice that nuclear radiation in a $250^{\circ}F$ 10^{-6} Torr pressure leak rates are generally below 10^{-5} cubic centimeters per second in a well designed joint. Nuclear radiation produced greater effects on blue line porosity. This is rather a high level radiation, I might add, for 10^{-8} and 10^{-9} rads are approaching nuclear levels. For design application in which adhesives must perform the dual functions of joining and sealing against the internal

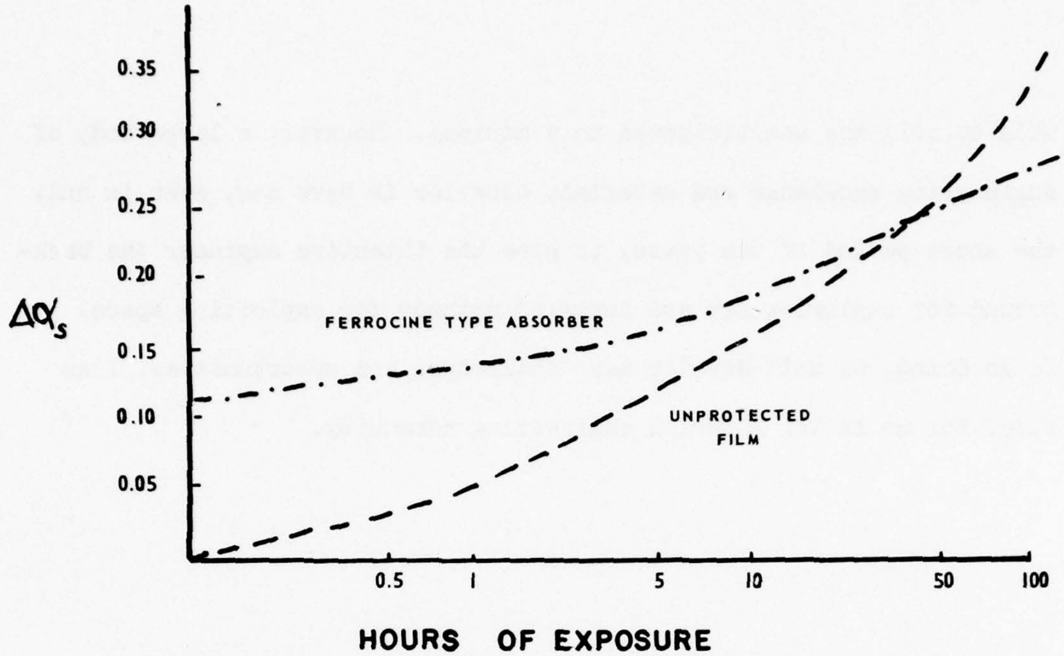
pressurization loss the additional use of an elastomeric sealant on the high pressure side of the joint would be recommended.

How about the temperature control situation? The function of thermal control for vehicle which depends on any significant time in space is carried on mainly by coatings whose purpose is to adjust the emittance and absorptance of internal and/or external surfaces. Energy in many forms reach the surface of the vehicle. There are the radiations of the sun, the earth's albedo, the earth's radiation, just to name a few. These radiations are largely converted to heat by the interaction with the vehicle skin. Furthermore, the electric systems within the vehicle generate significant heat of its own. Various coatings with suitable ratios of absorptance to emittance are used both internally and externally to control the temperature within the vehicle. Three primary classes of each coating are generally recognized as well as defined in problems of sensitivity to the space environment. Some may use coatings of metallic, ceramic and organic types. Each one has its own function depending upon the limit you want to establish in the absorptance to emittance rate. The principle interaction between the space involvement and organic coatings is the degradation of the coatings due to the absorptance of various wave energies. Ultra-violet, for example, will interact with coating polymers to cause oxidation and cross linking. The oxidation will result in the formation of these low molecular weight parts that I mentioned before and these will tend to

evaporate. Cross-linking due to ultra-violet will cause peeling and cracking of the coating, as well as color changes in the coating itself, which would affect the design ratio.



This graph merely shows the results of a ultra-violet radiation on the absorptance of several typical coatings. As time increases you can see we have a gradual diminuation in the value of the alpha or absorptance value. This would, of course, then change the conditions under which you would expect to be able to use this material significantly. An effective protection mechanism for this ultra-violet sensitive material is the addition of a strong ultra-violet absorber such as ferrocine.



Here is a development which came as the result of a study. You will see here, that while we do get some sacrifice in absorptance with the use of the absorber from the initial value after the 50 hours the additive is showing considerable improvement over the non-additive materials. The ferrocine is a compound which has an iron matrix in its midst, so to speak. These are just a few examples and like I say, one can go on endlessly.

In closing, as the size, complexity and dwell time in space of devices and vehicles increases, there is a certainty that unanticipated and possible undesirable effects will be observed which affect the performance of materials. Continued observation and thought is necessary both on the ground and in space to refine our experience and thus be

able to hold the unanticipated to a minimum. However, a large body of engineering knowledge and materials behavior is here now, even in only the short period of ten years, to give the inventive engineer the background for exploring new and improved methods for exploiting space. In so doing, he will develop new challenges and opportunities, I am sure, for us in the material engineering community.

SECRET

SPACE EXPERIMENTATION

presented by

MR. PAUL O'MEARA

U. S. ARMY FIELD OFFICE
U. S. AIR FORCE SPACE SYSTEMS DIVISION

LOS ANGELES, CALIF.

SECRET

SPACE EXPERIMENTATION

(U) The Army Field Office at the Air Force Space Systems Division is a small element of the Army Materiel Command, of which our hosts, WECOM, is a large element. Specifically, the Army Field Office is responsible for liaison between all elements of the Army and the Air Force Space Systems Division at Los Angeles, California. The fact that our small office exists is some evidence that the Army has an interest in developments in space.

(S) As you are aware, the Air Force is the responsible agency within DOD for programs and developments, for utilization of space; and the Space Systems Division is the specific organization with hardware development responsibilities. Within this framework, however, requirements for support of the Army in its' traditional roles and missions remain and continue to be the Army's responsibility. AR 70-36 recognizes the Army requirement to carry out Research and Development activities in the Research and Exploratory Development areas.

(U) Today I hope to give you an idea of space programs and experimentation in space, to review future possible courses of this experimentation, and, finally to talk about potential applications of space technology. Let us first look at NASA, and then DOD experiment programs.

(U) In NASA, the Mercury series of one-man flights primarily was intended to demonstrate that man could survive and function throughout an earth orbital mission.

(U) Within the series of Gemini two-man flights, in-flight experimentation has included a variety of physiological tests - bone calcium loss, heart condition, visual acuity, etc.; terrain and cloud photography; on-board navigation; environmental measurements -- electron density, radiation levels, etc.; and, of course, the well-publicized extravehicular activities.

DOD/NASA GEMINI EXPERIMENTS

NUMBER	TITLE
D-1	PHOTOGRAPHIC DEFINITION OF OBJECTS IN SPACE
D-2	PHOTOGRAPHIC DEFINITION OF OBJECTS IN NEAR SPACE
D-3	MASS DETERMINATION
D-4	RADIOMETRIC BACKGROUND MEASUREMENTS
D-5	STAR OCCULTATION FOR NAVIGATION
D-6	PHOTOGRAPHIC DEFINITION OF TERRESTRIAL FEATURES
D-7	RADIOMETRIC MEASUREMENT OF OBJECTS IN SPACE
D-8	RADIATION
D-9	MANUAL SPACECRAFT NAVIGATION
D-10	SPACECRAFT ATTITUDE DETERMINATION
D-11	TERMINATED
D-12	MODULAR ASTRONAUT MANEUVERING UNIT
D-13	ASTRONAUT VISIBILITY
D-14	UHF, VHF POLARIZATION MEASUREMENTS
D-15	LOW LIGHT LEVEL TV
D-16	MINIMUM REACTION POWER TOOL EVALUATION

Man's capability not only to survive for several weeks in a weightless environment, but also his ability to be reasonably alert at the end of

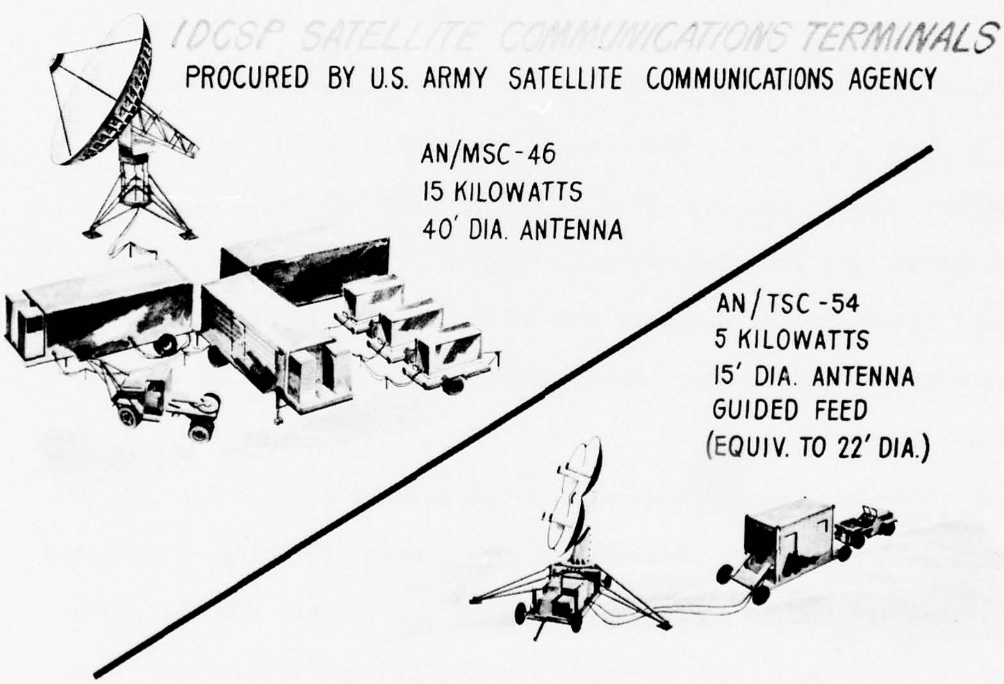
of this time has been demonstrated. That spacecraft can be precisely maneuvered has been demonstrated, as has the feasibility of useful extravehicular activity by an astronaut. NASA earth photography has shown that we can, indeed, see and recognize some detail on earth from space.

(U) With regard to the future, of course, the Apollo manned lunar landing program is the predominant NASA effort. There will be a series of Apollo earth-orbital research and development flights, on which some space for experiments (primarily scientific in nature) is available.

(U) The Apollo Applications Program (AAP) will enter systems definition in early summer, with two (2) contractors under contract to NASA. This is the only NASA manned spaceflight program firmly scheduled to follow Apollo. It will use much Apollo technology. Present plans call for earth-orbital flights of up to 45 days (with resupply) lunar orbital flights, and 14-day exploration missions on the lunar surface. Additionally, NASA has many unmanned scientific programs.

(U) NASA has issued publications outlining possibilities for secondary payload rides. Channels and procedures are being established between NASA and DOD to enable placement of appropriate DOD secondary payloads on NASA launchers. In addition to this activity, there is a small DOD group at NASA (Houston, Texas) concerned with the DOD experiments in the Gemini program. Whatever DOD experiments are done in the Apollo work will be coordinated by this group.

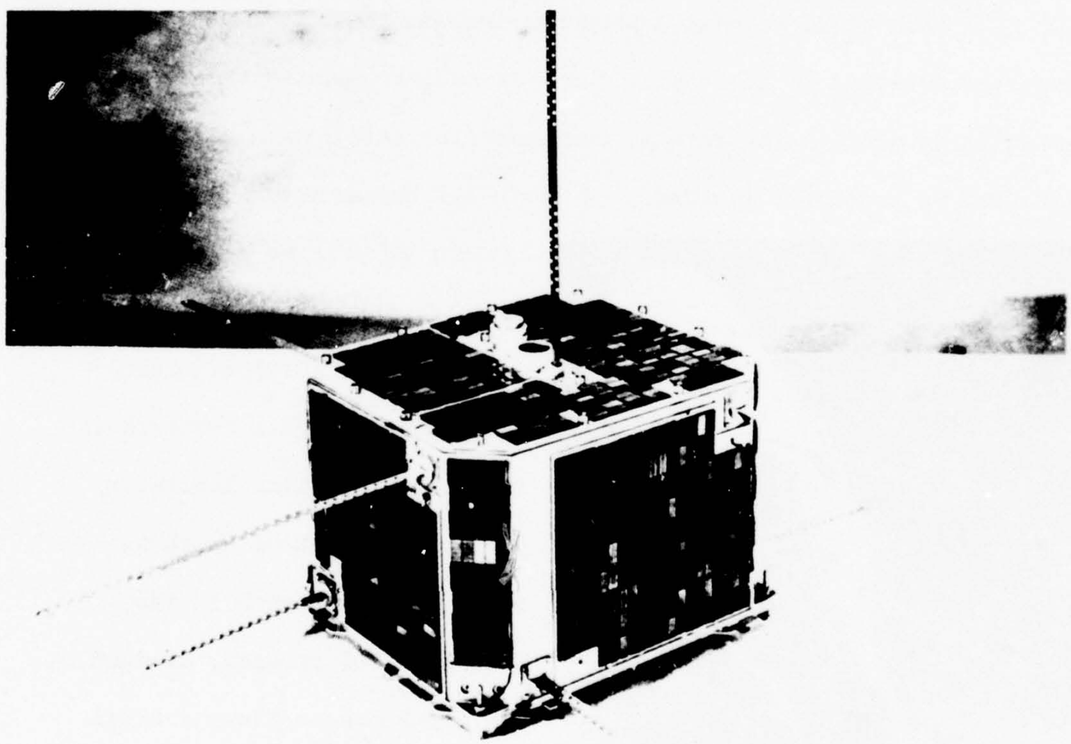
(S) The DOD now has several on-going satellite programs. The current Army space activities include participation in several programs as well as support to NASA. The Army is responsible for the ground environment for the Defense Communications Satellite program. This includes three projects: (1) the SYNCOM II and III satellites, originally launched by NASA. The Army operates ground terminals in Hawaii, Ethiopia, Viet Nam and Thailand for this system; (2) the Initial Defense Communication Satellite Project (IDCSP) involving a global network of ground terminals which are being developed by the Army, and



(3) the Advanced Defense Communication Satellite Project (ADCSP). The Army is participating in definition phase of ADCSP and will develop ground terminals for this system.

(U) The Army Corps of Engineers operates the Sequential Collation of Range (SECOR) geodetic satellite system. The SECOR system uses electronic ranging techniques to accurately locate land masses separated by large distances. This is a view of one model of the SECOR satellite. It is nearly one foot on edge and weighs 40 pounds. These satellites have been launched as secondary payloads aboard several boosters.

SECOR TYPE II SATELLITE



(U) Project HARP is conducted jointly by the Army Ballistic Research Laboratories and McGill University of Canada. It involves the use of smoothbore 5-inch, 7-inch, and 18-inch guns to propel probes to altitudes of about 400,000 feet.

(S) The Corps of Engineers has provided construction efforts in support of NASA. Also, within the Corps of Engineers, we have heard about Mr. Lowe's program of lunar studies.

(U) The Army Mobility Command has participated in lunar roving vehicle evaluations for NASA.

(U) The Natick Laboratories are developing and testing space suits for the manned space flight programs. The Laboratories also have developed foods for use in space, and food-dispensing techniques used by NASA, and probably to be used in the DOD MOL program.

(U) Air Force satellite programs include the continuing Discoverer series of launchers; the Vela nuclear explosion detection satellites; and initial defense communication satellites, soon to be launched as secondary payload on a Titan III Research and Development launch; as well as several highly classified programs.

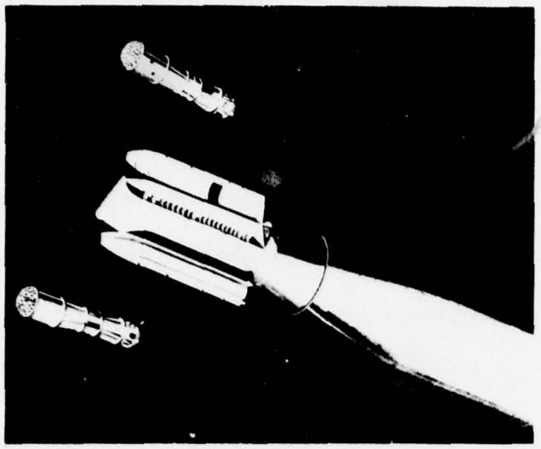
(U) The military manned effort currently is centered in the Manned Orbiting Laboratory (MOL); the first of which is scheduled for launch in 1969. This is a DOD program, managed by the Air Force to place several experimental manned laboratories in orbit. These will be a so-called integral launch. An empty

laboratory "can" probably to be launched by an up-rated Titan III booster, with an attached modified Gemini capsule. When orbit is achieved, the two-man crew, who occupied the Gemini at launch, will move to the laboratory "can" to perform various experiments. Upon completion of their activities, probably after about 30 days in orbit, they will return to the still-attached Gemini, abandon the MOL "can" and return to earth.

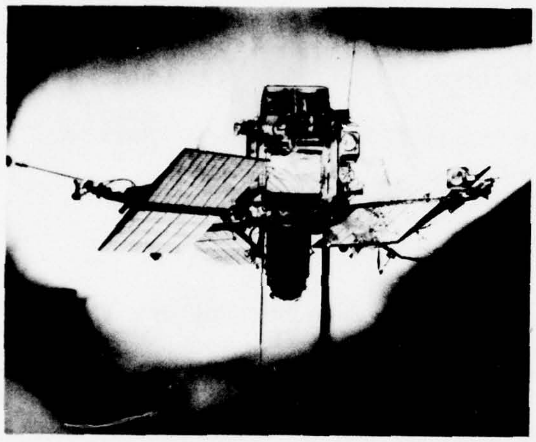
(U) Very briefly, and merely to establish a reference of booster capabilities: The Atlas Agena is capable of placing a payload of 6,000 pounds into a 300 nautical mile orbit or nearly 1,000 pounds into an earth escape trajectory. The Titan IIIC can place 23,000 pounds in 300 nautical mile orbit, or 5,000 pounds into an escape trajectory.

(U) Certain Atlas launchers and some R&D launchers of the Titan IIIC may have excess capacity. To get the "hitch hiker" and the booster together, in addition to the NASA coordinating groups already mentioned, DOD (DDR&E) has established two panels.

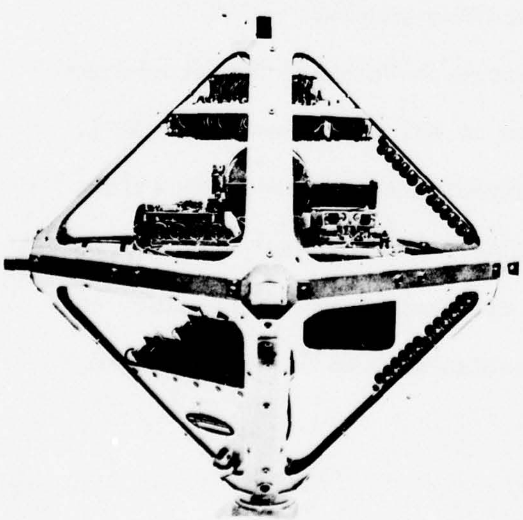
(U) The first of these, the Aerospace Research Support Program (ARSP) is run by the Air Force Office of Aerospace Research (OAR). They are concerned with support of experiments of the early effort type of thing. Specifically, in DOD terminology, ARSP supports space-borne experimentations in the areas of Research and Exploratory Development. The ARSP developed a series of orbiting vehicles to carry experiments. These include:



Orbiting vehicle 1 - This is an outgrowth of a ballistic pod, designed to fit on the Atlas. With guidance and propulsion, these OV-1 vehicles launched from Atlas space boosters can carry multiple experimental payloads. Several have been launched; a total of about ten are programmed.



Orbiting vehicle 2 - Designed to ride on Titan IIIC R&D launchers. This, also, is a multiple-experiment carrier.



Orbiting vehicle 5 - is a family of small tetrahedral satellites, each of which normally carries only one experiment.

Orbiting vehicle 4 - is a specialized communication experiment carrier. Orbiting vehicle 3 - Designed as payload for Scout solid rockets. Approximately 6 are now programmed. None have flown as yet.

(U) The OAR has prepared a handbook, outlining the ARSP program and describing vehicle capabilities. Facilities of the program can be made available, through intra-service channels.

(U) The other means of support for space experimentation is the Space Experiments Support Panel or SESP. This program supports work in the Advanced Development and Engineering Development DOD budget areas. It is managed by Space Systems Division of the Air Force Systems Command, with participation by the Army and Navy.

(U) Key points of SESP include:

(1) Projects nominated for launch support by the SESP must be funded in the Advanced Development or Engineering Development (6.3), or (6.4) or operational project programs.

(2) The agency requesting launch support must fund for the hardware which is to be flown, to include flight qualification. The SESP will provide funds for integration of the experiments hardware into spacecraft and for necessary launch support.

(3) Projects nominated to the SESP must have approval of the sponsoring agency and, in the case of Army projects, are submitted through command channels to Headquarters, Department of the Army, for final review and submission to the SESP.

(4) After submission of projects of all Services to the

SESP, an executive committee reviews the projects, establishes a priority of launch support for acceptable projects and sends the program to DDR&E for approval. The executive committee is made up of one representative each from Army, Navy and Air Force. The selection of experiments is made on their merit, without regard to service. The SESP also has published a book of instructions and has started programming for in-flight experiments for the next five years.

(U) Types of experiments submitted for inclusion in the SESP range from launch of communications, meteorological and SECOR satellites through spaceborne navigation systems development, ion engine, and space-maintenance studies.

(U) It is hoped that SESP and ARSP will be the programming and scheduling agencies for all DOD in-space experimentation. For the experiments, these programs offer an opportunity to obtain launch support without the need for furnishing the direct costs involved in securing a launch vehicle. Since the smallest booster now available for obiting small payloads costs something over a million dollars, this is a significant opportunity. At the same time, the experimenter must be prepared to deliver flight-qualified hardware on time to meet launch schedules. Flight qualification testing often involves considerable time and expense. For example, flight qualification of this SECOR geodetic satellite adds about 25% to the time and over 25% to the cost of obtaining similar hardware which does not have to be launched.

(U) <u>FUTURE</u>. Since it established the first radar contact with

the moon in 1946, and launched the first U. S. satellite, Explorer I, on 31 January 1958, the U. S. Army has continued to be active in the national space program.

(S) The continuing requirements of the Army call for support from space, perhaps in the areas of tactical and strategic communications, command and control, intelligence, geodesy, meteorology, missile and space vehicle detection and negation, and electronic intercept and countermeasures. Exploratory and defense capabilities to support lunar operations appear to be required.

(S) What about "farther out" possibilities? Martian and Venusian exploration, first unmanned and then manned, appears to me personally to be certain. Semi-permanent lunar scientific and quasi-military bases also to me appear to be in the near future. Lunar bases might serve as refueling and staging bases for interplanetary travel. In a military sense, they might be used as observation posts, retailiatory bombing platforms, command posts, possibly interplanetary interception bases.

(U) Capture of an asteroid for purposes of colonization, manning, or for military basing has been proposed. Some of the asteroids approach earth closely. Their orbits could be altered by atomic explosions properly placed on their surface. Such an earth-orbiting asteroid would have the same users as a moon base, and could in fact, be a competitor satellite to the moon.

(U) Dr. Sanger, in his book, "Space Flight," discusses a trip

to nearby stars in a constant acceleration nuclear powered spacecraft. The crew, due to effects of relativity, would age 30 to 40 years during the trip, while this journey of exploration would occupy several hundred earth years.

(U) The late Dandridge Cole in his book "Island in Space" discusses hollowing out the interior of a captured asteroid by focusing a nuclear explosion. While semi-molten, the asteroid would be spun-up to form an egg-shell-like structure. Upon cooling, colonization could take place on the inside of this spinning shell in a sort of inside-out gravitational field, and a man-made environment.

(U) Some of these things may not take place -- at least in my time! On the other hand, some of them probably will. It is incumbent upon us to prepare, and specifically to prepare the Army, for its role in these activities.

(U) I have noted some potential Army requirements in space. To fulfill them we need not reinvent the wheel -- DOD and NASA have done much work in material and biological areas and their relation to space. Means of testing are available; not only in space chambers, but also through the in-flight capabilities of NASA programs, and primarily through the DOD Aerospace Research Supported Program and Space Experiments Supported Program.

DEFENSIVE WEAPONS CONCEPTS FOR A LUNAR BASE

presented by

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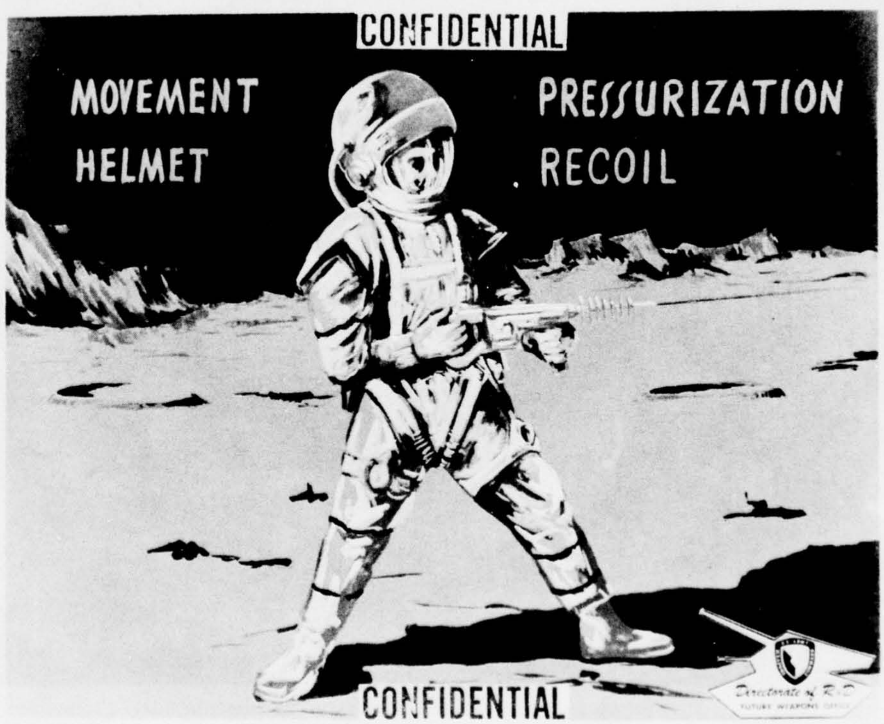
R&D DIRECTORATE

U. S. ARMY WEAPONS COMMAND

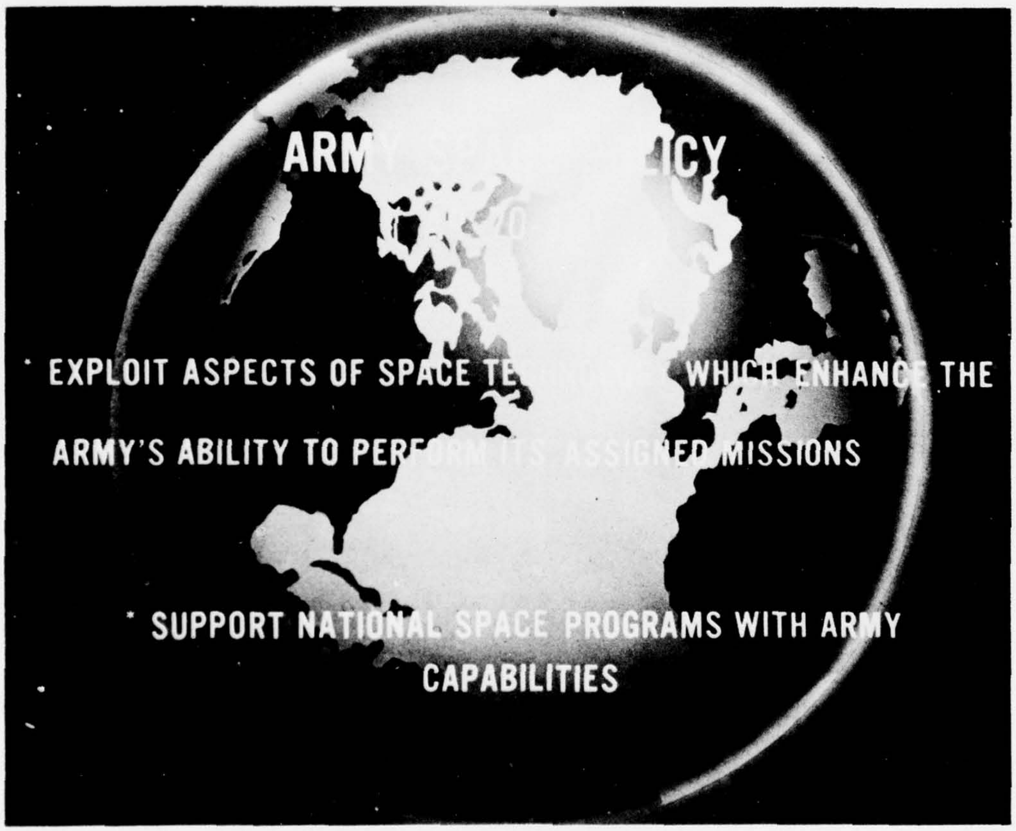
ROCK ISLAND, ILLINOIS

DEFENSIVE WEAPONS CONCEPTS FOR A LUNAR BASE

(C) As you may, or may not know, the Army Weapons Command has been active in trying to stimulate interest in a defensive weapon space program. Initial discussions with people from both industry and government agencies disclosed that for the most part, very limited thought had been given to the possibility that a space environment would present an entirely new set of ground rules for weapons design. Besides the hostile environment of vacuum and temperature, there are several human engineering problems to be overcome. The space suit will of necessity be pressurized.

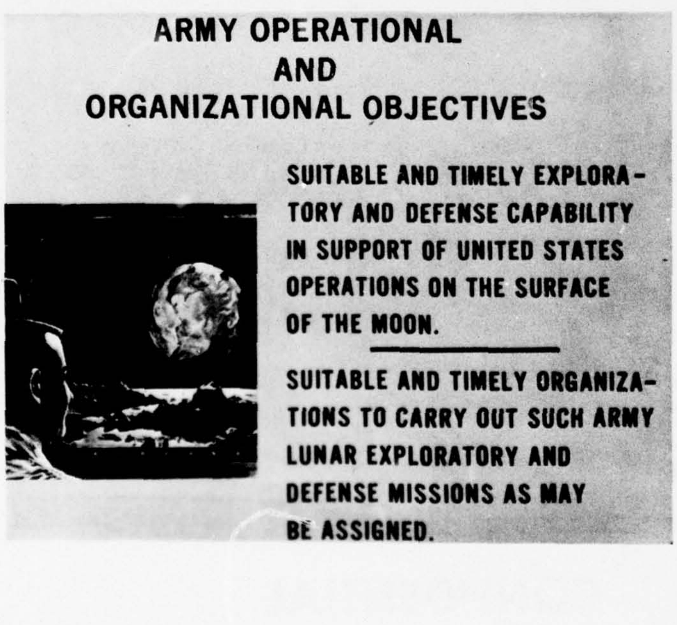


This will restrict freedom of movement and reduce the capability to manipulate weapon mechanisms. The space suit helmet will reduce the ability to use weapon sights. The ballooning effect of the space suit may prevent any kind of weapon from being steadied against the body when it is fired. This, and the low acceleration of gravity on the moon may require a considerable reduction in recoil momentum. These are only a few of the factors that present entirely new and different requirements to a weapon designer.



(U) Our interest and efforts here at the Weapons Command are not based upon our own fancy, but as stated in AR 70-36; "It is the policy of the Department of the Army to exploit those aspects of space technology which can enhance the Army's ability to perform its assigned missions." The Department of the Army also supports national space programs, such as those conducted by the National Aeronautics and Space Administration. These are supported with Army capabilities and facilities, as directed by the Secretary of Defense. For the purposes of this briefing, the applications of space technology to support Army functions are of primary interest.

(U) AR 70-36 also points out that all of the Services may conduct research and exploratory development to discover new ways to use space technology. This authorizes Army agencies to carry out R&D activities in space projects funded under expl ratory development programs.



(U) Operational and organizational objectives, together with materiel development objectives for extraterrestrial activities, are contained in the combat development objectives guide, more commonly known as CDOG.

The Army operational and organizational objectives include suitable and timely exploratory and defense capabilities to support U. S. operations on the moon, examples are the lunar base teams of the Apollo program. The initial team of which is programmed for the early 1970's. These CDOG objectives state a requirement for capabilities, at an appropriate time, for operations on the moon and other planets. As you can see included in the material desired are individual equipment and weapons.

CONFIDENTIAL

QUALITATIVE MATERIEL DEVELOPMENT OBJECTIVE

EQUIPMENT FOR OPERATIONS ON THE MOON AND OTHER PLANETS

MEANS TO PERMIT SURVIVAL AND CONDUCT OPERATIONS ON OTHER PLANETS; THESE INCLUDE SHELTER, FOOD, CLOTHING, INDIVIDUAL EQUIPMENT, WEAPONS, COMMUNICATIONS, VEHICLES OR OTHER DEVICES FOR FACILITATING MOVEMENT, AND SOURCES OF POWER.

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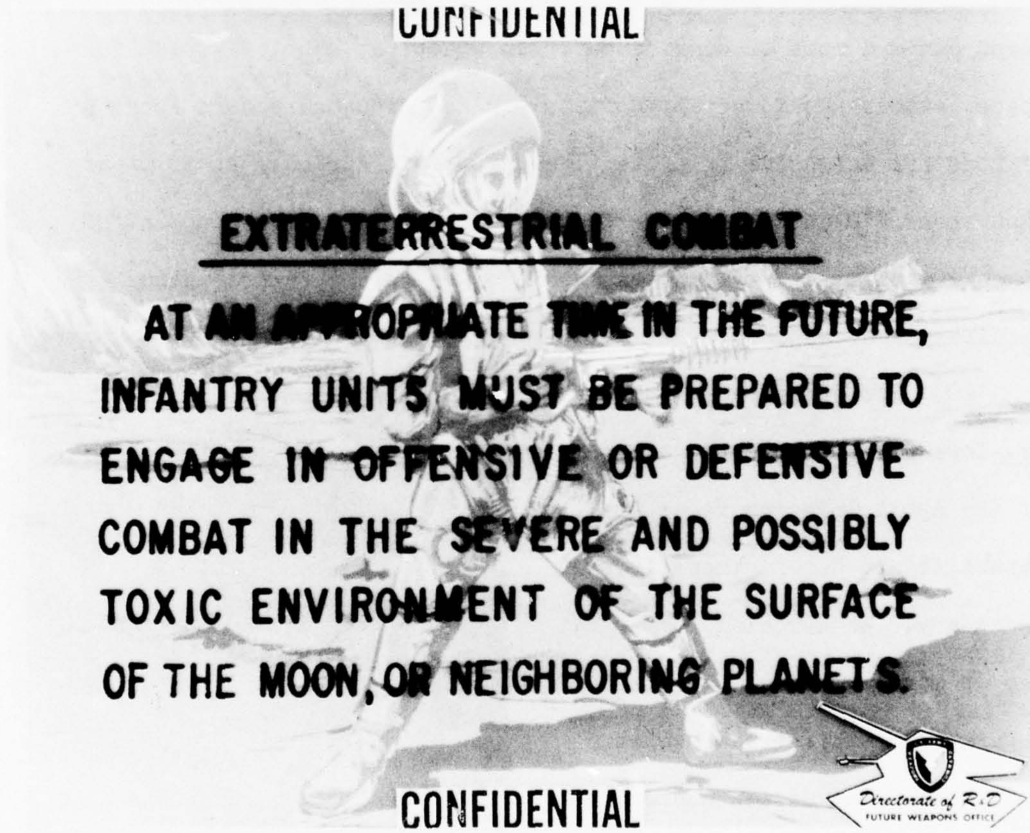
(C) It should be recognized that the Army extraterrestrial mission will be established by higher authority. Material development objectives must be established to be prepared for such an eventuality in order to avert surprise by a hostile enemy. The objectives stated in CDOG provide guidance for the Army to look ahead so that the necessary capabilities are available when such a mission is established. For example, this is a CDOG paragraph in the infantry operations chapter. It clearly states the need for a defensive hand held weapon



at some time in the future to be used on the moon and other planets

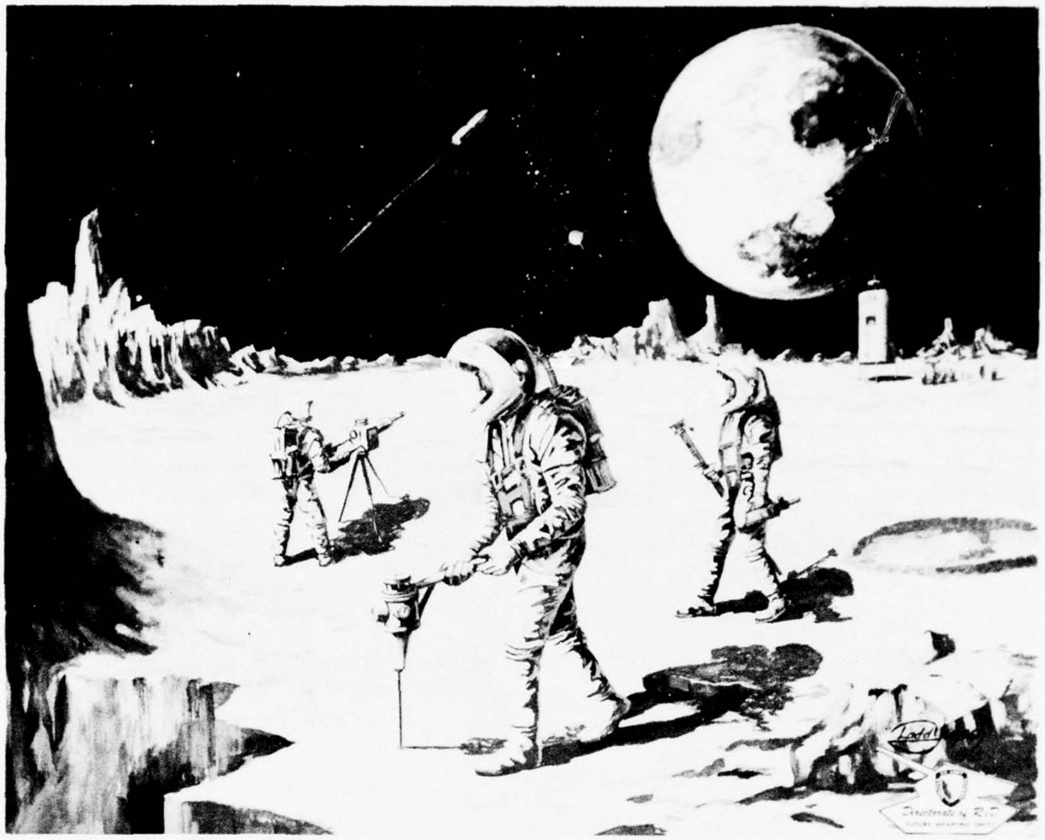
if and when needed. In considering the development of weapons for use in outer space, it is important to recognize that the United States has international commitments in this field. The United States has agreed that outer space will be used for peaceful purposes and that weapons of mass destruction will not be employed in outer space.

(C) There are, therefore, constraints on weapons activities for space applications. Nevertheless, the development of technologies which might be needed in the future to provide individual defensive means can and must be carried out. In practice, R&D activities for space weapons should be appropriately classified and should focus on weapons for defensive or protective purposes. Further, it is clear that these R&D activities are to provide a basis for development of space weapons, if a situation should arise in the future which requires such weapons.

(U) The lunar base team that Mr. Lowe discussed in his briefing of the Apollo program needs the capability to defend themselves if necessary. We certainly hope that two or more countries can operate separate scientific bases on the moon peacefully as was successfully accomplished at the South Pole. However, this country has learned

from experience that the only way to exist in peaceful coexistence is to be prepared. There was an article in the 9th February 1966 Washington Post, datelined "Geneva, February 8th." Let me quote directly therefrom: "Russia warned today that military circles planned to set up bases on the moon. The chief Soviet disarmament negotiator, Semyon Tsarapkin, told the 17-nation disarmament conference that the prospect of lunar bases made it all the more imperative that the delegates get on with their task. Replying to congratulations on the successful landing of the Soviet moon probe Luna 9, Tsarapkin said military circles were already scanning the moon to establish military bases there. He did not specify which military circles he meant." I think this emphasizes our need for a much larger effort in space weaponry exploratory development than both the Army and private industry are currently supporting. But first we must do some basic thinking on the application to a moon environment.

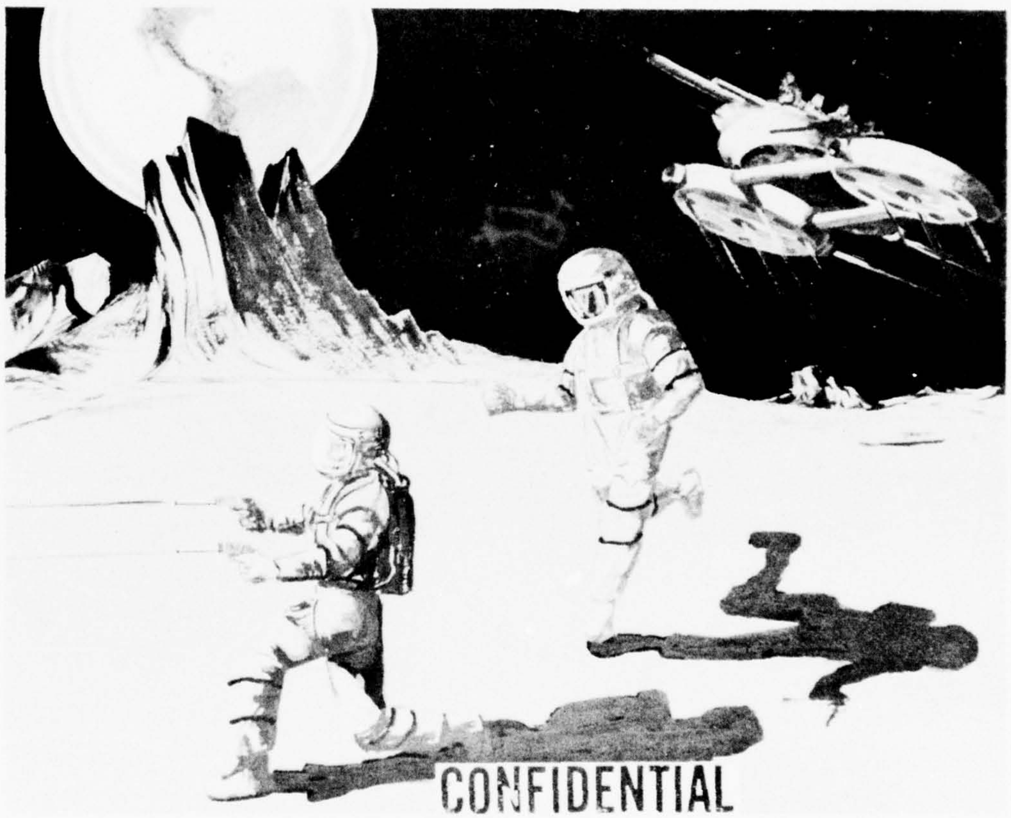
(C) Weapons designed for use on the lunar surface against men or vehicles must be lightweight, simple to operate, and be capable of one or two-man operation. Since precise aiming of handheld weapons will be difficult because of the constraints of the pressure suit, weapons easily pointed are preferred. Area fire fragmenting weapons that utilize rock, stone or whatever the lunar surface is found to be made of may be very advantageous. The use of such indigenous materials will preclude the cost of transporting extra weight to the moon, which is quite costly at $5,000/pound. Fragmentation weapons are



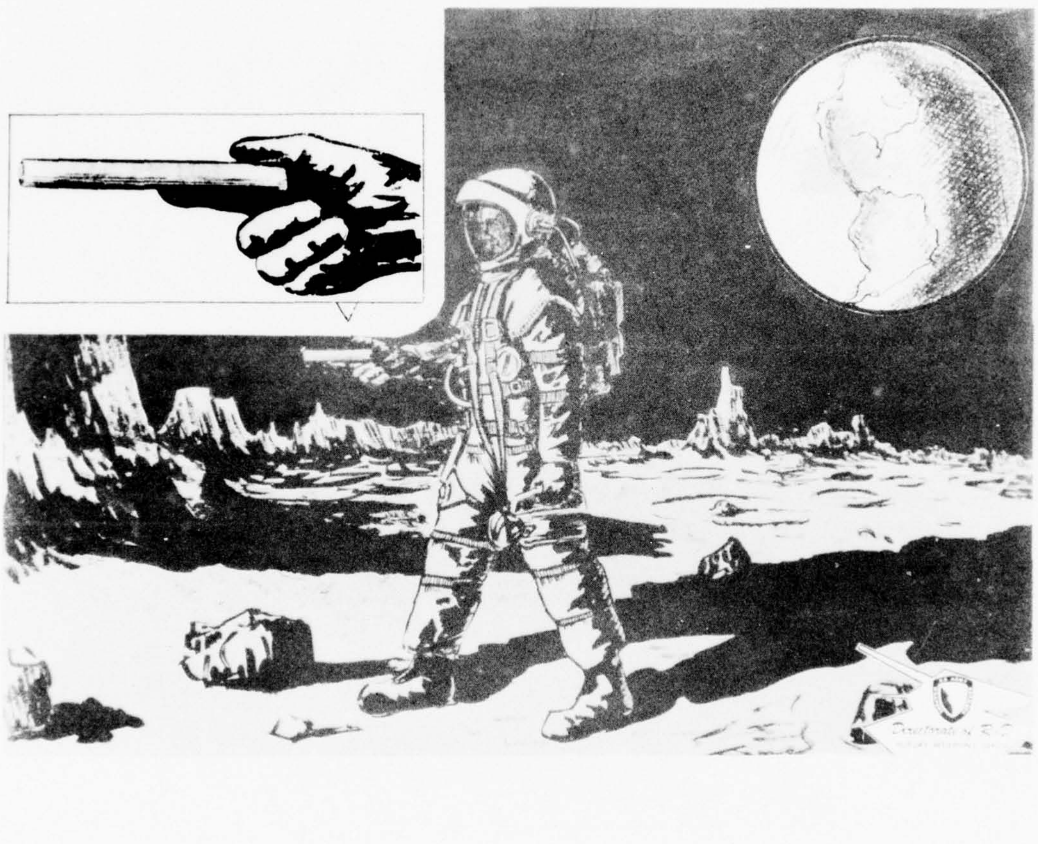
potentially very useful against personnel for their performance improves when there is no atmosphere to retard the fragments. However, it may be desirable to keep the fragment velocity below the orbital velocity on the moon to prevent filling the surrounding media with floating debris. Any handheld weapon capable of penetrating thin skinned surface vehicles will more than likely provide the initial defense. On the moon, penetration of a pressurized vehicle may be tantamount to defeating it. In spite of many yet unsolved problems,

the use of laser weapons is a distinct possibility for lunar operations. However, even if these problems can be solved, it will remain to be determined if such weapons offer significant advantages over explosive weapons. Current estimates are that laser weapons will not be available in a practical size until 1985.

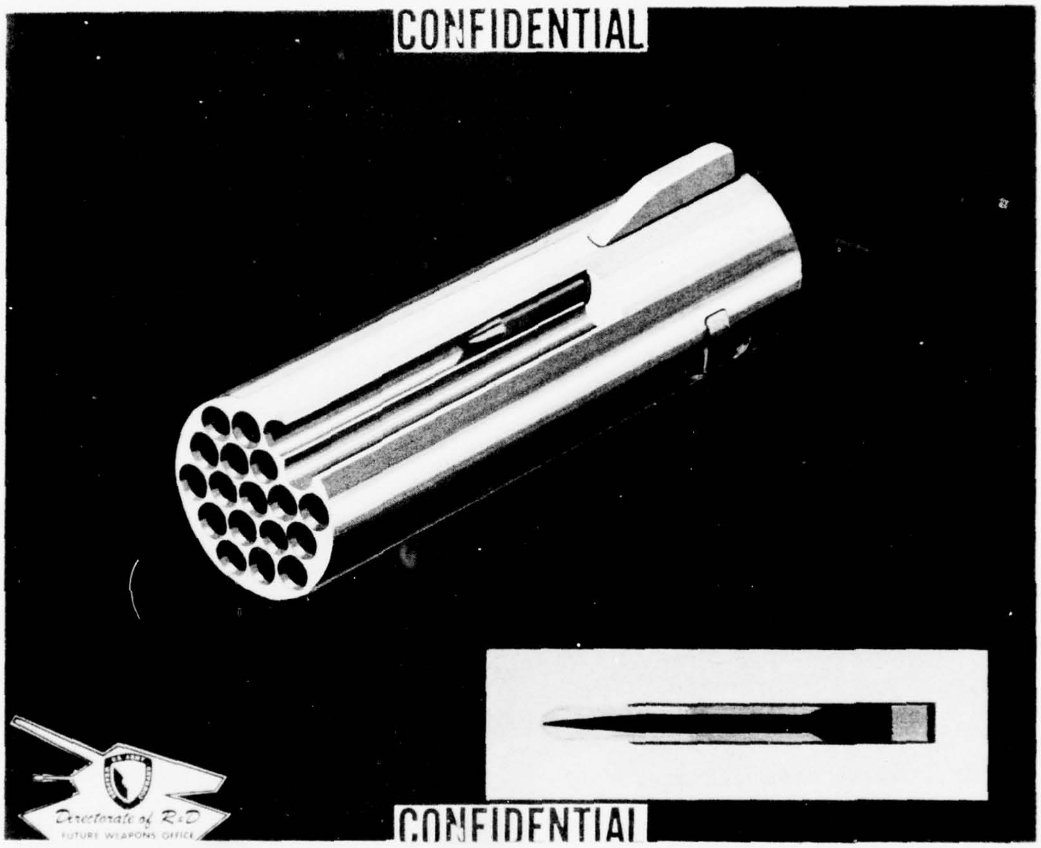
(C) The Advanced Development and Planning Branch here at the Weapons Command has generated one concept and ideas for six others. Our illustrator has visualized a combination Western and Flash Gordon type operation. He's entitled this "High Noon on the Moon."



Something probably more down to earth, or rather down to moon, is shown here. The item in hand, shown in the exploded inset, is a nineteen



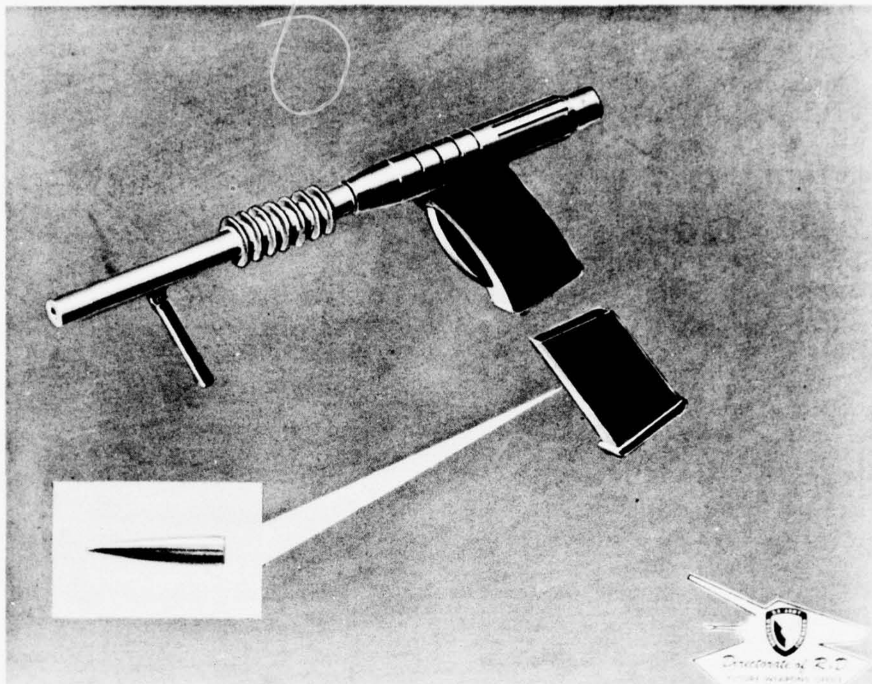
round handheld weapon. It fires a flechette of about one-half grain with a slow spin. The slow spin stabilizes it against mal launch



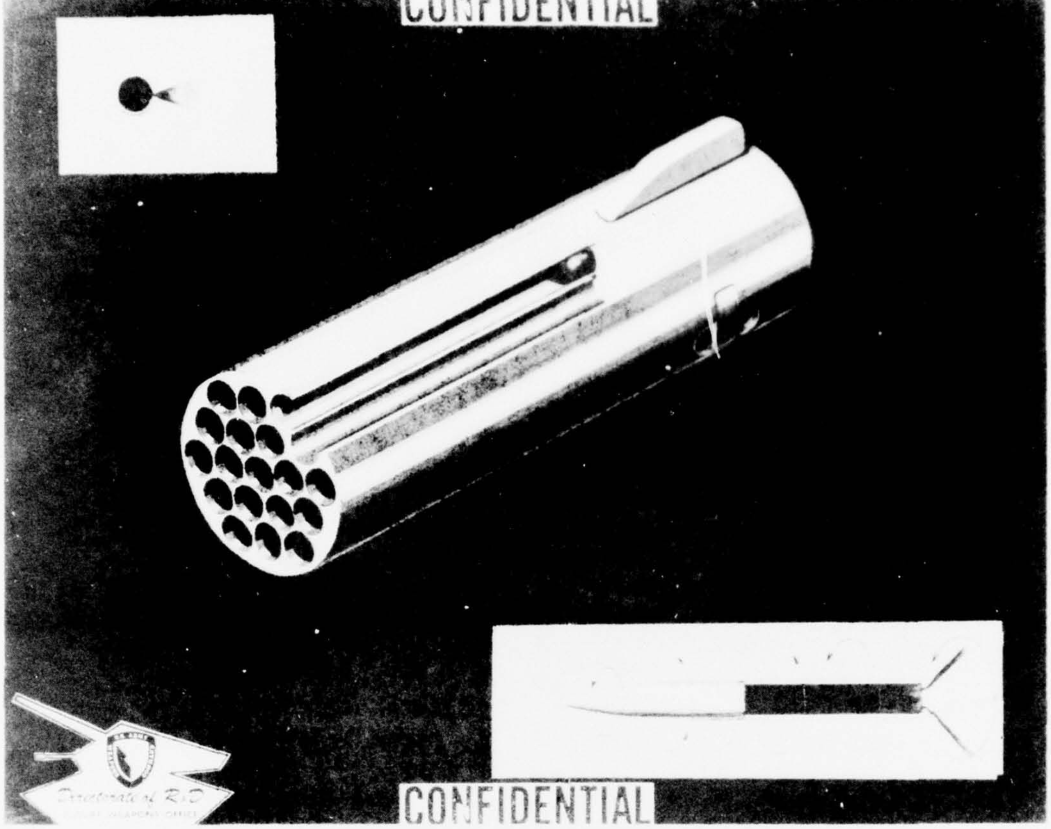
conditions when fired in a vacuum. The fins provide stabilization in an atmosphere such as on earth. This gives it a dual capability. Its total weight is less than one pound. It is 7.5 inches long and one inch in diameter. The flechettes have a velocity of 3,000 fps with a peak chamber pressure of less than 15,000 psi.

Our illustrator has taken some artistic license in showing a possible final application. The concept you have just seen was published under the title "The Hornet."

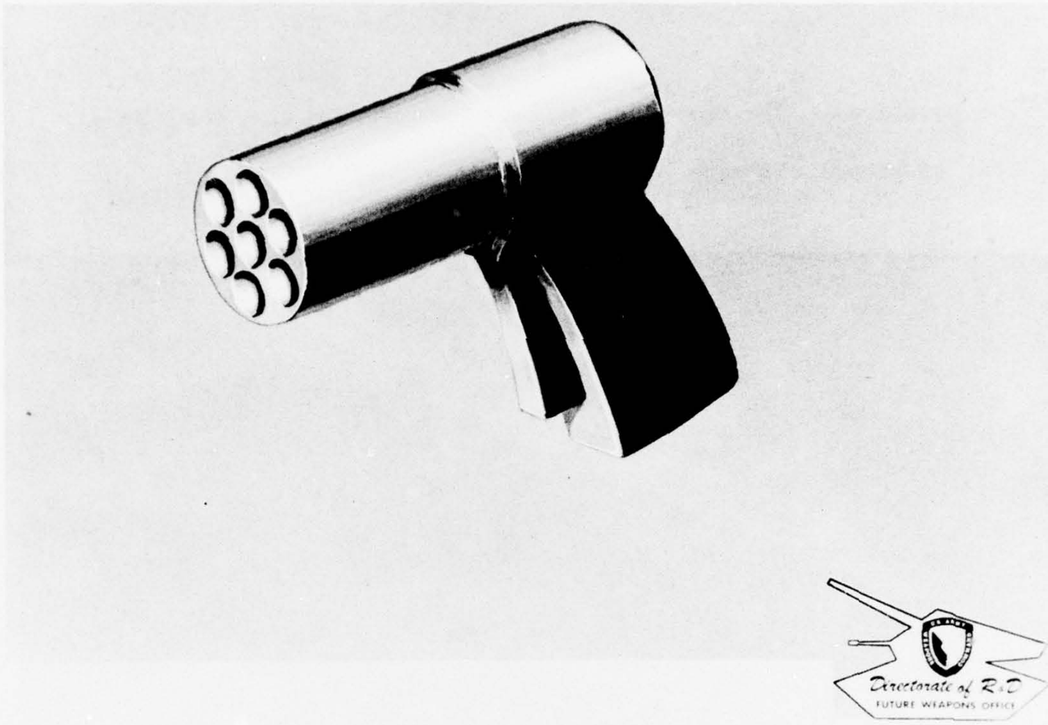
In addition, we have six ideas whose feasibility have not been determined but are presented here to stimulate thinking. So let there be light.

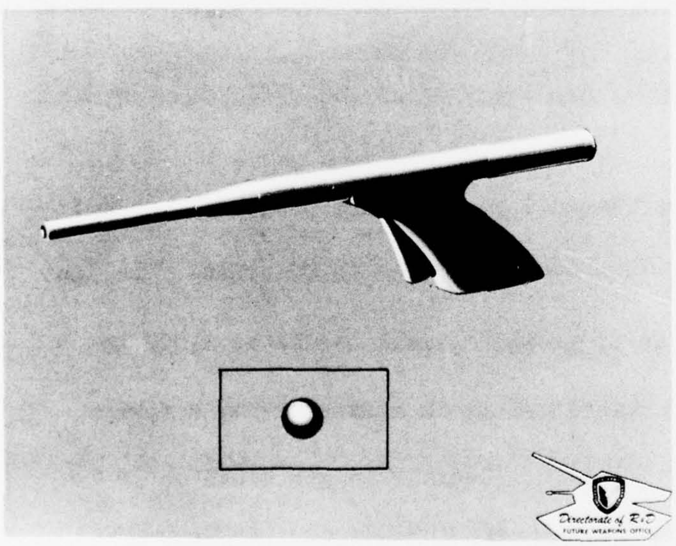


The first of these is a spin stabilized micro-gun firing a cal. .14 projectile from a rifled bore at a velocity of 3-4,000 fps. Total weight is estimated at 2-4 pounds with an overall length of 1-1/2 to 2 feet. The magazine is estimated to hold from 30-50 rounds. Although the rings on the barrel give it a Buck Rogerish appearance, they perform a useful function. Since there is no atmosphere on the moon, there can be no cooling of barrels. The only way to dissipate the heat from the barrel is by radiation, and these rings increase the radiator surface area. The next one is a variation of "The Hornet."



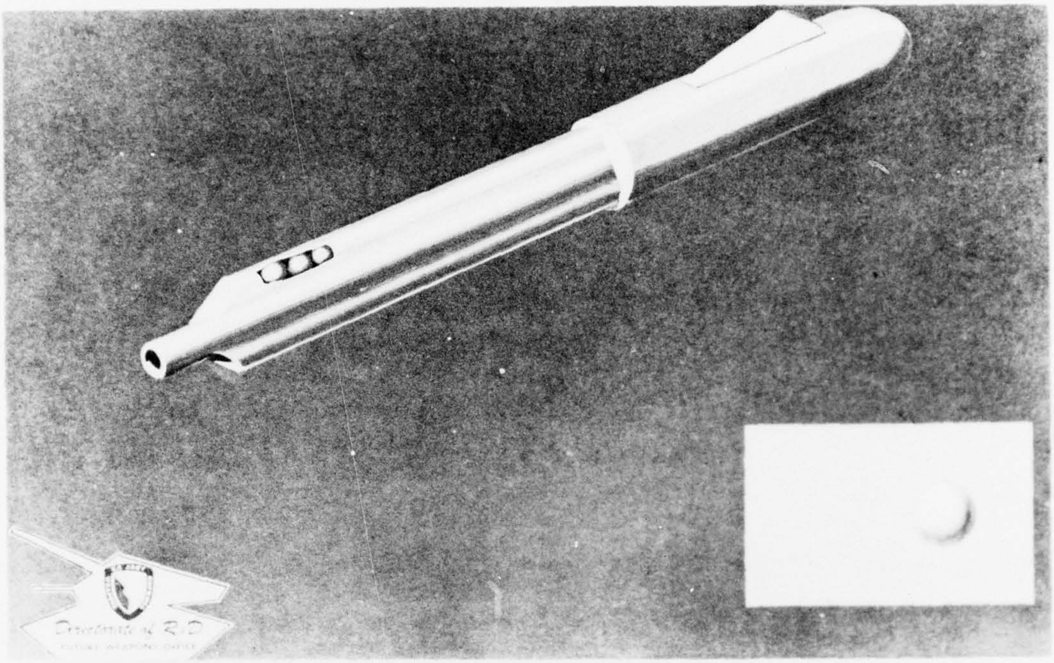
It utilizes the same launcher to fire either a small spin stabilized rocket or a spherical projectile that is propelled much like a balloon that is suddenly released. The difference being that the launcher provides a definite direction to the projectile. The next idea is one that takes the gases from an explosion and directs them in a concentrated stream. Its useful range is only 3-6 feet when there is no atmosphere to retard the gases. This range may be improved upon.





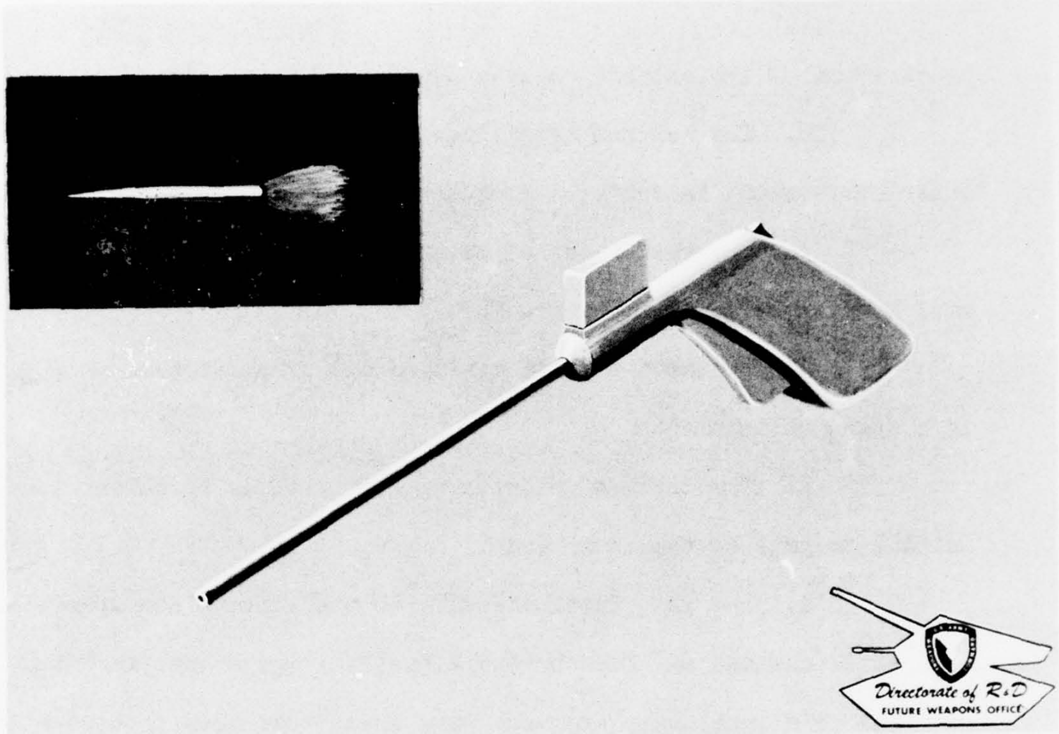
This idea shows an 8 grain spherical projectile being propelled by a cocked spring. The muzzle velocity is very low, around 300-500 fps. Its weight is 3-6 pounds, with a length of 1-1/2 to 2 feet. It would be necessary to recock the spring after each round. This is relatively an inefficient way to propel a projectile and upon investigation, may not turn out to

be too practical. The next idea utilizes compressed gas, such as air or CO_2, to propel either a hollow or solid sphere.



This gun can be made for an estimated 2 pounds. The projectile velocity is around 1,000 to 1,500 fps. The overall length is 8 inches. The last idea also uses a compressed gas to propel a small needle at 1,000 to 1,500 fps. The projectile is stabilized in an atmosphere by a fuzzy tail, thus giving it a dual capability. Overall length would be 12 to 16 inches.

(C) These are all ideas that need further investigation to



determine their feasibility. There are also many other areas that need investigation. Any program will have to identify these problem areas associated with the hostile environment of space before hoping to find their solutions. To lend direction to such an exploratory program, several areas that sorely need answers are:

a. The space threat defined in terms of the target, tactics, and weapons;

b. The mission and tactical doctrine for space operations;

c. The capabilities and limitations of current weapons and weapon mechanisms in a lunar environment;

d. The affect of a lunar environment upon impact and

penetration of typical projectiles and target materials;

e. The maximum recoil energy that can be tolerated in a lunar environment including a consideration of the space suit design;

f. The best types of materials to be used when two pieces must move in relation to one another;

g. The best type of ignition and propulsion means for use in a space environment;

h. The optimum velocity of a projectile to defeat the initial targets on the moon; and

i. The spin rate necessary to stabilize a non-spherical projectile against mal launch conditions in a space environment.

(U) I'm sure there are many more areas that need investigation and which can be investigated under simulated conditions here on earth. For those problems that need answers that cannot be obtained under simulated conditions, it is possible to put some experiments aboard orbiting vehicles and probes. However, much is yet to be done here on earth before we are ready for experiments in space.

(U) This concludes the formal presentation. If anyone has any questions or discussion on anything covered, we will be glad to entertain them at this time.

DISCUSSION SESSION

DISCUSSION SESSION

Question: (U) Within the Army, what agencies are primarily interested in this effort? Names of agency and contact?

Answer:

Mr. Wagner: (U) First off, the AMC of which the Army Weapons Command is a part, is primarily interested in this effort. Contacts at the Weapons Command would be myself; at AMC, Colonel Ellis' office or Dr. Hudson.

Mr. O'Meara: (U) AMC has just put out a real fine revised version of their little book about doing business with AMC. This was put out by the Industry Relations People at AMCRD. It names the interests of all the major commands.

Mr. Wagner: (U) How would you get a copy?

Col. Rieger: (U) You write to the Commodity Command with which you do business or to the Industrial Relations Office at AMC.

Mr. Wagner: (U) There are other agencies that have a primary interest. Naturally, the office of Chief of Engineers, Extra-terrestrial Research Agency - Mr Lowe will be the contact there, (Room 1103). Frankford Arsenal has an interest and Jack Donnelly is the contact there. In fact, Jack and I formed what we call the Lunar Tech Information Centers, jokingly referred to as "Lunatics" because right now most of those who have not thought

about our future in space, think of us as this. At RIA, Arnie Kester or J. Melow would be the contact point there. I think these are the primary agencies which would have an interest along this line.

Question: (U) Will funding support be available from the Army, and can it be anticipated?

Answer:
Mr. Wagner: (U) Right now we have no money. Sometime in the future money could become available. We do not know when. I do not think we can anticipate this until we solve our commitments in Vietnam, because most of the money that we would be using on things like this is being funneled over there. I do not think I should try to hazard a guess at this point in time.

Question: (U) Should a company wish to perform an in-house program, will the Army provide a need to know access to available data? If yes, what agency or individual should be contacted for assistance?

Answer:
Mr. Wagner: (U) If a company wants to spend their own money on this, we are encouraging them to do so at present. There is a non-funded study program which is set up to take care of this. By signing an agreement, you obtain a sponsor and in the case of an exploratory program on

weapons, it would more than likely be the Weapons Command, but this is assigned through AMC. This program then allows you to obtain all the guidance and information you would need to conduct this in-house unfunded study. Major Ferrari at AMC is the office which you go through, and they usually approve or disapprove and assign a sponsor. In our case, it would be Bill Smith or me at the Weapons Command that would give you assistance. The place to start is here at the Weapons Command.

Question: (U) What is the relationship between the Army's current and planned efforts to the activities of NASA and other agencies?

Answer:

Mr. Wagner: (U) Actually, this is one of these things that is very sensitive. NASA, of course, is a firm believer completely that space is for peace, and this is as it should be, because their mission is the peaceful application of space. They leave anything else up to the Army and the Air Force. It is up to the Air Force to put these items into orbit or to get them there, and once they are there, it is up to the Army to maintain it. I do not know quite how to further answer, unless someone would like to help me. Dr. Hudson, can you help me on this question?

Dr. Hudson: (C) It seems to me that the view point we have and should take is one of weapons pursued in an extremely

light and highly technical form that has to do with capability. We would be in a difficult way to undertake, at least in a developmental category what is clearly and solely a space item and yet that may be an extremely important part of it. I think we can do exactly what needs to be done with this view point. I do believe it is extremely important for all of us connected with this to be quite careful of our language so that we do not jeopardize what may be a very useful and important program by saying the wrong thing at the wrong time. It will take work and will take aggressive imagination and careful laying on to establish the approval we need. While I am speaking, I will just add one small question. I do not quite see why it is so important to avoid having projectiles go at the escape velocity on the moon. Space is so big, why should one worry?

Mr. Wagner: (U) I think there is a critical area there. Escape velocity may be fine, orbital velocity is what we are trying to avoid.

Dr. Hudson: (U) Your probability will probably turn out to be extremely small. If this significantly influences your effectiveness, then why impose this as a requirement?

Mr. Wagner: (C) I think this is a very good point. It is something that we will have to determine. What we have said here

this morning is only somewhat of our own thinking, and you are correct, it may turn out that a much higher velocity is what is required to get the effectiveness.

Dr. Hudson: (C) We should examine the trade-offs. It may be advantageous and an asset, for certain types of weapon configurations, that its velocity remain within some category. Let's be quite careful not to impose constraints or requirements early in the game, unless they are real. In many cases, this is just one good example, it seems to me that a situation should be open.

Mr. Wagner: (U) It could very well be, and I think this is something we do need to determine. It is just another problem that right now we do not have an answer for.

Question: (U) Will the Army provide advisory direction to company-sponsored effort?

Answer:
Mr. Wagner: (U) I think we answered this, it is emphatic "yes." We will provide them all the guidance that they need or that we can provide. I am sure that there are a lot of questions they could ask that we do not have answers for. However, if any work is done in this area, it should be appropriately classified for obvious reasons.

Question: (U) Is there a document that summarizes the best available information on the moon environment? In other words, is there a piece of paper that summarizes the moon's environment?

Answer:

Mr. Lowe: (U) I assume this means a document available for distribution. There will be an engineer's document available in about 45 days which will summarize the present lunar model as it is being used by the Corps. It will be available first by direct inquiry in a limited number and then later available thru the Defense Documentation Center. It will be an unclassified document.

Col. Rieger: (U) There are several public domain documents that are available on the various parts of the moon. For example, there are 4 or 5 SAE papers on the lunar surface, materials, and items in this category, as they apply to lunar surface vehicles and travel. There are 2 or 3 very fine Rand studies on the physical characteristics of the lunar environment, but there is no single document that I know of that wraps the whole thing up in what we will find on the moon.

Mr. O'Meara: (U) There is an Air Force Cambridge Research Laboratory handbook of geophysics and space environment that talks about other things besides the moon which I think is a very fine document.

Question: (U) Just about 1.56785 times in every meeting or wherever any space people get together there comes up the word "cold welding" and I'm still trying to run this victim down. The word cold welding to an engineer presents a certain picture. I have been unable to find this cold welding except in words. Is there anyone here who has put his hand on some cold welded material and couldn't pull it apart? Anybody? This is the 1400th time I have asked that question and I'm still looking.

Answer:

Mr. Rubin: (U) I think the question you raise can be answered. For instance, you can get copper to cold weld rather readily. It is a question of real clean surfaces. I think a lot of theoretical studies have shown that if you look at what they call the solid solubility of materials in each other, materials which have this high solid solubility in each other under strong pressures will cold weld. For instance, you can get copper to do this. If you take real hard materials which have oxides and which have low solubility in each other, generally you can squeeze them pretty hard and they will not cold weld.

Mr. Lowe: (U) As we move ahead, we should enlist the help of others in this search for that clean cut example of something that happened that falls within the engineers' viewpoint

and understanding of the term cold welding. Sure, anybody has galled a nut on a bolt when they've turned it up too tight, but I'm talking about cold welding of materials where, when we get through, we've got a welded joint.

Mr. Rubin: (U) You can ultrasonically weld copper to glass, yet by the tenents I've just discussed, large dissimilarity and solid solubility, it shouldn't be done. So I admit there is probably a large area of theoretical uncertainty which still needs exploration.

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